PLANTERS' RECORD

VOL. XLII

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JANUARY TO DECEMBER

THE HAWAIIAN PLANTERS' RECORD

VOL. XLII

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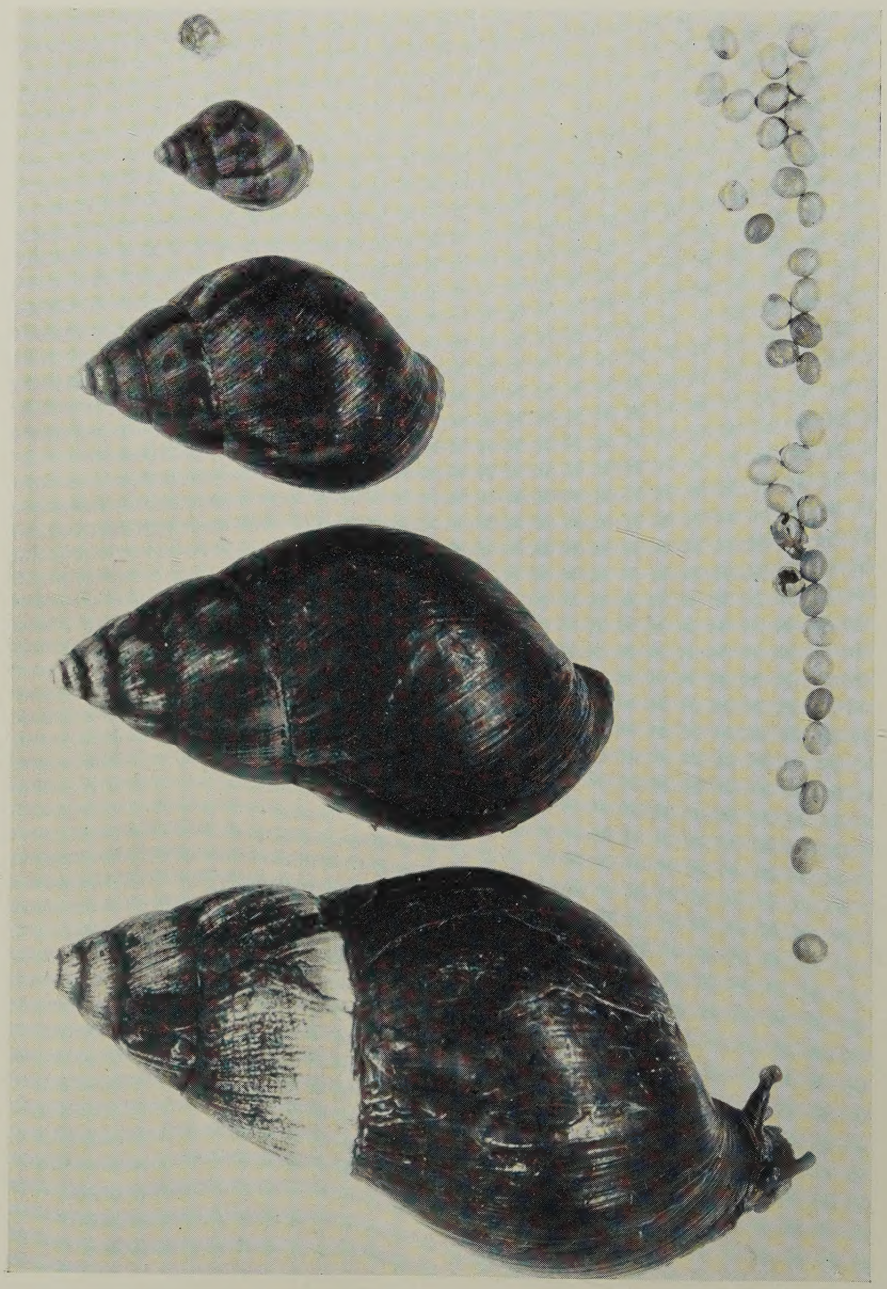
TABLE OF CONTENTS

	Page
Upendra Kumar Das	1
Chemical Weed Control	3
The Prebaited Feeding-Station Method of Rat Control	39
Utilization of Molasses—II	77
Utilization of Molasses—III	89
Sugar Prices	97
Susceptibility of Unhusked Rice (Paddy) Versus Polished Rice to Rice Weevil Attack	103
A Refinement in the R.C.M. Determination of Phosphate in Soil	105
Occurrence of the Grass Mealybug *Antonina indica* Green on Sugar Cane	107
A *Bufo Marinus* of Exceptional Size	109
The Plant Food Value of Nitrogen in Filter Cake	111
The Analysis of Plant Material for Total Nitrogen, Phosphate and Potash—An Improved and Simplified R.C.M. Procedure	119
Some Sugar Yield Relationships	125
Stem Galls of Sugar Cane Induced With an Insect Extract	129
The Giant African Snail *Achatina fulica* (Fér.) Discovered in Hawaii	135
Defining Colloidal Solutions	141
The Introduction Into Hawaii From Mexico of Insect Parasites to Control Armyworms (1923-1924)	147
Introduction Into the Hawaiian Islands of Mexican Enemies of the Avocado Mealybug	153
Sugar Prices	159
Some Aspects of the Chemistry of Soil Colloids	163
Trapping Sugar Cane Beetle Borers at Kailua	167
Non-Replaceable Potash Fixation	175
Occurrence of the Minor Elements in Commercial Fertilizers as Determined Spectrographically	185
Selenium—I	197
Some Insect and Other Animal Pests in Hawaii Not Under Satisfactory Biological Control	211
Sugar Prices	231
Sugar Cane Collecting in New Guinea During 1937	235
An Annotated List of the Fungi and Bacteria Associated With Sugarcane and Its Products	247
Sugar Prices	314

ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XLII

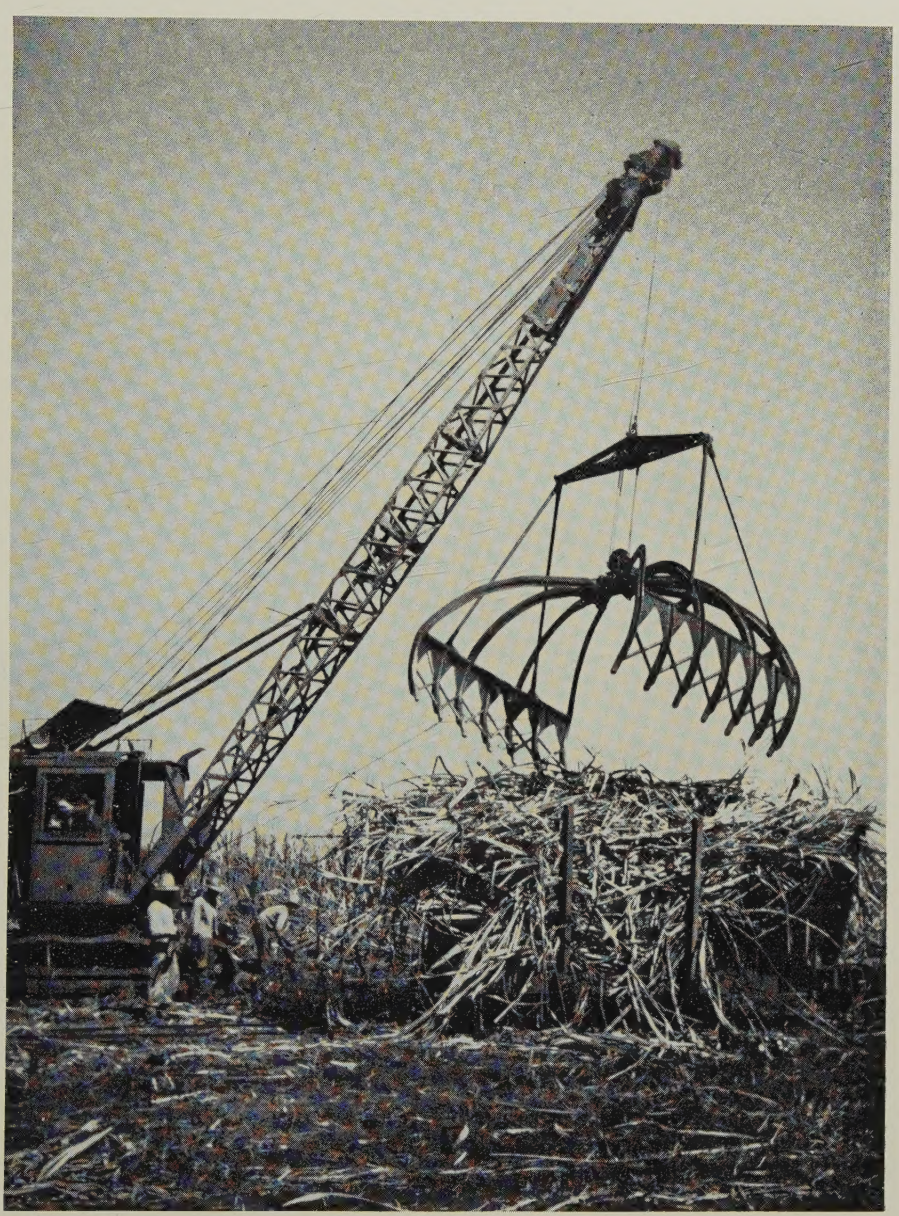
FIRST QUARTER

Rat feeding station No. 145 being prebaited with unpoisoned oats prior to final baiting with thallium-treated rolled oats.



Giant African Snail—Young and adult in natural size—eggs slightly enlarged.

THIRD QUARTER



GRAB HARVESTER

Cane gardens filled with many varieties of *S. officinarum* are found near all the villages on the Ramu plateau of New Guinea (elevation 5500 feet). Photo by C. E. Pemberton.

THE HAWAIIAN PLANTERS' RECORD

Vol. XLII FIRST QUARTER 1938 No. 1

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

Upendra Kumar Das

It is with deepest regret that we record the accidental death of Dr. Upendra Kumar Das in his biochemical laboratory on October 22, 1937. Without doubt the part he was taking in research connected with problems of the sugar industry was an outstanding one, and it will be difficult and perhaps impossible to find another scientist motivated by the same practical viewpoint which he held.

As a student after coming to Hawaii in 1924, his record was one of which to be proud. At the University of Hawaii he completed the work for his Bachelor's degree in three years and was graduated in 1927 with honors, and this was done while he was earning his own way, and also finding time to join and eventually lead the University soccer team. After graduation, although then employed, he continued his studies in the biological chemistry laboratory and received his Master's degree in 1930. Later securing a leave of absence from his work, he spent a year in residence at the University of Minnesota and was granted his Doctor's degree there in 1935. His election to the national honor society, Sigma Xi at Minnesota, bespeaks the record he made there.

The life of Dr. Das was intimately connected with the Experiment Station. While still a student, he was employed as a part-time student assistant and upon his graduation in 1927 he was appointed an assistant agriculturist. Thus he learned to know sugar cane as it grew in the field under many and varied conditions. This experience contributed to all of his work thereafter, and gained for him the respectful attention of the fieldmen in whose problems he became interested.

His contributions to sugar cane agriculture were conspicuous. His discovery and perfection of the method of preserving cut cane stalks with their tassels has been largely responsible for the success of the crossing technique that is now used by our cane breeders. His collection of sugar cane crosses made in India in 1929 added another lot of breeding material to our collection. His studies of weather records laid the foundation for a simple measurement of effective temperature and added much to our understanding of temperature-yield relationships. Recently his work on the nature and progress of sugar storage in the cane plant, and particularly the key role played by nitrogen fertilization in connection with cane quality has given us new facts and a new understanding of cane ripening. Still more recently, his in-

vestigation of the possible values in some sugar mill by-products has attracted a respectful attention.

Dr. Das was a generous contributor to *The Hawaiian Planters' Record;* and was ever willing to share his keenly analytical point of view with his associates. He will be remembered for his constructive suggestions, and for his optimism, his happy nature, and his personal kindness. R. J. B.

In This Issue:

Chemical Weed Control:

The purpose of this article is to bring into small compass data and discussions based upon experiences and recommendations of specialists throughout the world who have developed chemical means for combating the growth of weeds.

Advantages and disadvantages of various chemicals, when used for specific herbicidal purposes, are enumerated. Hazards, precautions and safety measures, which may be of aid to the worker engaged in chemical weeding pursuits, are cited.

The Prebaited Feeding-Station Method of Rat Control:

The rat is acknowledged to be a real economic as well as a health menace in many sugar cane areas. A plan of rat control by prebaiting in field areas with unpoisoned bait followed by poisoned grain is described in detail. The materials and equipment are described and illustrated, and the best baits and attrahents with the concentrations of poison are discussed. The results of a series of experiments that have been carried on at intervals since 1935 are given with tables and illustrations.

Utilization of Molasses:

The results of a beef cattle fattening experiment, using a ration of which 83 per cent was local by-products, are presented. This experiment was run in cooperation with the Hamakua Mill Company, Hawaii, using steers from Kukaiau Ranch. The rations included molasses, bagasse, pineapple bran, and cane tops, with soybean oil meal for the protein component.

The chief purpose of this experiment was to test the pen-fattening (dry-lot) method under our conditions, and to compare the quality of beef produced with that produced by similar animals on excellent pasture. The most important results were in the quality of the carcasses. In the pasture-fed group 20 per cent of the carcasses were rated "good," and in the pen-fed groups 50 per cent were "good." The amount of marbling of the meat was greater and its flavor much better in the pen-fed carcasses, indicating an improvement in market quality which would bring an increased price in an established and discriminating market.

A long-time feeding experiment with a ration including 55 per cent of sifted bagasse gave results indicating that its feeding value is considerable. The experimental animals were rabbits, which were exercised in a machine and fed on this bagasse ration over a period of two-thirds of the normal life span of the rabbit.

A growth experiment with kiawe bean meal, which is or may be used in many areas of the Territory as a constituent of by-product rations, indicates that its proteins are of fairly good quality, and that 30 per cent of the meal in a ration gives excellent results.

Chemical Weed Control

By Francis E. Hance

CONTENTS

	Page
Introduction	4
Sodium and Other Chlorates	4
Applications of Chlorates	5
Dry Chlorates	7
Effectiveness of Chlorates	7
Aftereffects of Chlorates on Crops, Soils, Humans and Animals	9
The Fire Hazards of Chlorates	10
Summarizing the Discussion on Chlorates	12
Oil Sprays	12
Less Common Weed Eradicants	13
Ammonium Sulfate	13
Ammonium Persulfate	14
Ammonium Thiocyanate (also called Ammonium Sulphocyanate)	14
Borax (Sodium Borate)	15
Calcium Cyanamide	15
Carbon Bisulphide (Carbon Disulphide)	16
Copper Sulfate	17
Dyes	17
Iron Sulfate (Copperas—Green Vitriol)	18
Kainite	18
Sodium Bisulphate (Nitercake)	19
Sodium Bisulfite	19
Sulfuric Acid	20
Zinc Sulfate	22
Zinc Chlorate	22
Arsenicals	23
Properties of White Arsenic	23
The Effectiveness of Arsenic as a Herbicide	23
Sodium Arsenite	24
Acidulated Solutions of Arsenic Compounds	24
Comparison and Discussion of Formulae Published by Various Authors for the Preparation of the Acid Arsenical Spraying Solution	25
The Kephart-Normann-Carn Formula	25
Robbins-Crafts Formula	25
Arsenic Pentoxide (As_2O_5)	26
The Fixation, Toxicity and Stimulation to Plant Growth of Arsenic Applied to the Soil	27
Discussion on the Toxicity of Arsenic to Vegetative Growth, as Compiled from the Literature	27
Toxicity of Arsenic to Animals	32

Introduction

Ball, Madson and Robbins (12) observe that less effort and expense have been expended upon the elimination of weeds than to the reduction of the ravages of insect and fungus diseases and that in spite of this fact that weeds cause more loss to agriculture than do insects and fungi combined. They state:

Few people, probably, ever realize what a burden weeds add to human existence. The production of almost all crops largely consists of a battle with weeds. The preparation of many products of the soil for human consumption involves the elimination of weeds or their effects. Weeds may cause illness or even death in men or animals. They militate against our full enjoyment of the outdoors; they are the bane of every home owner and amateur gardener. Few human activities, in fact, are not affected in some measure by weeds—pests which increase the cost of our food and clothes, hamper our movement, menace our health, and dampen many of our pleasures.

Weeds have been said to levy, in one way or another, an annual tax on agriculture and industry in the United States of about three billion dollars. No estimate has been made of the weed tax in California, but it may be safely assumed to be at least proportional to the country as a whole, or a minimum of sixty million dollars, the larger portion of which falls on agriculture. Indiana estimated in 1920 that its average annual loss through weeds was $210 per farm; Wisconsin's estimate in 1927 was about $244 per farm.

Weeds cause losses in many ways, the more important of which are as follows:

1. They offer serious competition to crops for plant food, moisture and light.
2. They add to the cost of crop production because of the large amount of labor necessary to keep them in check.
3. They increase the cost of preparing many crop products for consumption.
4. They impair the quality and destroy or reduce the value of many products of the soil.
5. They harbor insects and fungus pests destructive or injurious to economic plants.
6. They are sometimes poisonous and may endanger the health or life of men and animals.

A review will now be presented citing, without needless repetition, typical examples of chemical weeding practices as reported by workers throughout the world. Descriptions and classifications will be made of the chemicals employed, their proven effectiveness, their hazardous nature, if any, and their toxic effects, if reported, on desirable vegetation, on soils and on animals and humans.

Sodium and Other Chlorates

(Quotation: In bags, powdered, $0.065 to $0.10 per pound, f.o.b. New York)

Chlorates are non-poisonous after partial or complete decomposition. They are effective herbicides for certain types of weeds. Their disadvantages include various degrees of induced soil sterilization and the fire hazard which accompanies their use, particularly their careless use.

Sodium chlorate ($NaClO_3$) is used more extensively than any other single chlorate compound. It is slightly hygroscopic and readily soluble in water. One drop of a solution of phosphorus in carbon disulphide placed on a crystal of sodium chlorate explodes with violence when the carbon disulphide evaporates in the course of a few seconds.

A crystal of sodium chlorate, if rubbed on the side of a box of safety matches, will emit sparks. Serious accidents are on record which have occurred with persons carrying tablets of chlorate of potash (throat remedy) in a pocket with a box of safety matches.

Chlorates decompose when brought in contact with weeds and other organic matter. The decomposition liberates free or nascent oxygen, the latter supposedly

destroying the weed tissues. It is commonly believed that in destroying weeds a chlorate liberates all of its oxygen, leaving a residue of table salt (NaCl). This belief has not been established as fact. Undoubtedly residues of undecomposed chlorates persist for some time. This assumption is supported by the ease with which chlorate-treated weeds may be kindled when dry and to the rapidity and severity of the fire which follows.

Chlorates are constituents of certain pyrotechnic mixtures used in fireworks displays. Chlorates should be used with a full understanding of their dangerous properties. Specific suggestions are made for handling this type of chemical under "The Fire Hazards of Chlorates" and "Aftereffects of Chlorates on Crops, Soils, Humans and Animals."

Applications of Chlorates:

Wakabayashi (114) reports a satisfactory weed control using a few pounds to 200 pounds per acre of a chlorate as a spray solution, depending upon thickness of the weed carpet. He found the treatment most efficient when 2 months of good weather followed its application.

Bickmore (17) states that chlorates are not economical on arable land, but that the practical sphere of their usefulness is confined to highways, railways, tennis courts, paths, etc. When used on arable lands, however, he suggests that the application of from 200 to 600 pounds per acre dry chlorates be broadcast, depending on character of weeds and soil. To destroy ragwort *(Senecio sp.)** and soft-leaved weeds in pastures, without doing damage to grass, he recommends the use of a 2½ to 3 per cent sodium chlorate spray solution, one gallon to 15 square yards. In heavy wet soil he advocates a dry mixture of 12 pounds of sodium chlorate and 100 pounds of sand or limestone. Four to 5 pounds of the mixture are applied to 10 square yards. For paths and courts he found a 10 per cent solution effective; ½ gallon per 10 square yards. He states further that the amount of water used to dissolve the chlorate is not important, provided there is sufficient solution used to insure good distribution. He has also found it to be of no advantage to employ concentrations greater than one pound of sodium chlorate to one gallon of water.

Walker (115) reports an effective control of Johnson grass *(Sorghum halepense)*, using a spraying solution prepared from 20 pounds of sodium chlorate in 50 gallons of water. The rate of application varies with severity of infestation, the average being 5 gallons of solution per 50 square feet. The above-ground portions of the grass are sprayed while the soil at the bases of the plants is fairly well soaked with the chlorate solution. In general, two or three chlorate treatments are necessary for a complete kill, applications being made at 2- or 3-week intervals. More satisfactory results are obtained by spraying on dull days as contrasted with applications made during sunny weather.

Grau (43) uses a stronger chlorate solution than either Walker or Bickmore. He states that one pound of sodium chlorate in a gallon of water is very effective in controlling Canada thistle *(Circium arvense)*, sow thistle *(Sonchus oleraceus)*, pep-

* The botanical terminology used in this paper has been contributed or has been checked by E. L. Caum, Associate Botanist, this Experiment Station.

per grass *(Lepidium virginicum)*, bindweed *(Convolvulus arvenses)*, Johnson grass *(Sorghum halepense)*, Bermuda grass *(Cynodon dactylon)* and quack grass *(Agropyron repens)*. Two applications are made, one in the spring after vegetative growth is well established, and a final treatment in the autumn.

Woodman (119) recommends the use of "spreaders" in 5 to 15 per cent solutions of sodium chlorate as generally effective with most weeds. He states further that the broadcasting of (dry) sodium chlorate, 200 pounds per acre, in the autumn, cleared very weedy land of couch grass *(Agropyron repens)*, crowfoot *(Ranunculus sp.)* and shallow-rooted perennials. Deeply rooted weeds were not affected.

Kiesselbach, et al (66) have found liquid spray or dry applications of sodium chlorate very effective against bindweed *(Convolvulus arvensis)* and hedge bindweed *(Convolvulus sepium)*. Four hundred to 480 pounds per acre were sufficient for first treatment. The spray solution (2 pounds per gallon) used was double the concentration employed by Grau (43). They recommend that application be made in autumn or in summer if the season is one of ample moisture.

Zahnley and Pickett (122) have used a solution of sodium chlorate, one pound per gallon of water, 150 to 200 gallons per acre, as a control of bindweed by making three successive applications in August, September, and October.

Light applications to the soil of compounds of zinc are occasionally made as a control in zinc deficiency of certain plants or as a remedy in plant disease. Neidig and McCallum (84) have patented a zinc chlorate mixture as a herbicide which may warrant experiments in weed control on areas deficient in zinc. The patented mixture consists of a chemical combination of zinc sulfate and sodium chlorate in which the zinc salt is present in excess of the amount required to balance chemically in combining with the sodium chlorate. However, the mixture is not recommended for cultivated lands, but rather for railways and highway right-of-ways.

Pulverized or finely ground chlorate added to limestone, raw rock phosphate, sand or other carriers are proposed from time to time as more efficient and economical than water solutions of chlorates. Under "Fire Hazards" mention shall be made of a report by Grau (42) in which it is claimed that weeds destroyed by chlorate powder mixtures are less liable to be ignited by spontaneous combustion than the same weeds destroyed by chlorate solutions. In describing his experiences with powdered chlorate mixtures, Willard (117) states that mixtures of finely ground sodium chlorate and limestone do not have a tendency to cake and, in preliminary trials, have given satisfactory results in weed control.

There is quite a variety of patented herbicides on the market which contain the chlorates of either sodium or calcium (or both) and, in some cases they carry, in addition, an absorber of moisture such as calcium chloride or magnesium chloride. An illustration of a product of this character may be found in the description of a patent granted to R. N. Chipman (28) in Germany. The herbicide consists of a mixture of 2 parts of calcium chloride and 3 parts of sodium chlorate. Another patent granted to Heath (54) in the United States describes a similar product crystallized at a temperature above 60° C. from approximately an equimolecular solution of calcium chloride and calcium chlorate.

For the eradication of perennial weeds, Arny, Bridgford and Dunham (3), at the University of Minnesota, apparently did not find it necessary to employ a sodium

chlorate solution greater in concentration than 12½ per cent (one pound chlorate in one gallon of water). They applied the solution as a spray at 125 to 150 pounds pressure to the tops of living weeds and used dry chlorate when weed foliage was partially dead. They found these treatments effective regardless of weather conditions, but recommend that the applications be made when the weeds are in bloom or when they are nearing maturity. These investigators state that it is desirable to wet the weed tops thoroughly and that as much solution as 2 gallons per square rod may be required.

Dry Chlorates:

At the present time, on some Hawaiian sugar plantations, consideration is being given to the use of dry or slightly moist herbicide powders for application to weeds (not the soil) as a substitute for the liquid spray. The purpose, of course, is chiefly a matter of reducing the costs of providing, transporting, and handling large quantities of water. In a discussion between the author and Raymond K. Conant, Agriculturist, Olaa Sugar Company, Ltd., a tentative formula for such a powder, it was agreed, in addition to a concentrated weed poison, should contain a small percentage of a bland oil to function as a leaf "sticker" and dust inhibiter, and a small quantity of a caseine glue to facilitate leaf adherence in rainy weather. A large proportion of pulverized raw rock phosphate might be used as a carrier and dilutent. Eventually such a powder would reach the soil and in most cases the phosphate rock it contained might well form a part of the next scheduled fertilization. The fraction of weed toxin in this proposed mixture must be selected with due consideration being given to its residual effect on soil and the subsequent crop. If the area to be treated were to be left in fallow for a half-year or more in wet, warm country, chlorates may be used, perhaps, with no ill aftereffects.

The use of chlorates in an area to be maintained in continuous cultivation might prove unwise because of chlorate soil sterilization. Muenscher (83) has found in New York State that the application of dry sodium chlorate, in late autumn, directly to the soil surface (200 to 600 pounds dry chemical per acre, in one application) destroys deep-rooted perennial weeds during the ensuing winter, but that the chlorate is decomposed only to a point by *the following summer* which would permit *some* crops to be grown. Many other workers report more active and longer chlorate soil sterilization. Additional comment on this point will be made later.

Effectiveness of Chlorates:

Users of chlorates do not invariably agree on the effectiveness of this chemical in destroying weeds.

Walker (115) at Hana, Maui, it was noted, sprayed above-ground portions of weed plants with a 5 per cent sodium chlorate solution and also "fairly well soaked" the ground at the base of the plants with the same solution. He reported that 2 or 3 applications of the spray at intervals of 2 or 3 weeks were required for a complete kill, although small weed patches were eradicated by a single treatment.

Using a maximum of 200 pounds of sodium chlorate per acre, Wakabayashi (114) claims to have destroyed the underground portions of weeds, but he added that it required 2 to 3 months to accomplish this.

Crafts (33) found chlorate treatment of weeds most effective, as did Walker, by applying the chemical to both soil and plant. He states that in many cases weed roots were destroyed 3 feet below the soil surface and that a thorough single spraying was usually as effective as 3 light applications.

In general, experimenters with chlorates find the sodium salt more effective than others which may compete with it in equivalent concentrations or on a cost basis. Meadly (76), in Australia, supports this statement; likewise do Thornton and Durrell (108) in Colorado.

Complete eradication of white top *(Erigeron annuus)* was accomplished by Hulbert, Spence and Benjamin (57) using 2 applications of chlorates 10 days apart. A third treatment was no more effective.

When depending upon chlorates to destroy weed roots, conditions in the soil approaching optimum warmth and moisture favor effectiveness of treatment. On the other hand, in dry soil, even in warm weather, Davidson (35), in Idaho, found chlorates quite ineffective. Warmth and moisture appear to be essential if maximum herbicidal action of chlorates are to be realized. Good drainage must be assured if toxic aftereffects are to recede in a reasonable period of time.

Many observers, who appear to be qualified to make such statements, claim that applied chlorates are absorbed by weed surfaces and subsequently are translocated throughout the plant. The net result is its ultimate demise.

Loomis, Smith, et al (73), for instance, state that apparently sodium chlorate penetrates all the external surfaces of the plant with the exception of that part having unusually heavy cuticle. After penetration, they state, its movement within the plant is by the xylem and is most rapid in the direction of the transpiration stream. These investigators state further that chlorates may be absorbed by the roots and rhizomes of plants and thence be translocated to the tops. In such cases, the entire plant is destroyed.

On the contrary, Aslander (4) published experiences, the substance of which appear to indicate that no harm occurred to the roots of thistle *(Circium arvense)* when a chlorate spray was applied so that no solution reached the soil. Direct applications to any part of the root system killed the tops in a few days, but the only portion of the root which died was that part which came in *direct contact* with the chlorate solution. He stated that chlorates can be transported through a root system without harming the parts through which the transportation takes place and that in order to kill all the roots of a plant, chlorates *must* be applied over the entire area where roots occur.

Under some conditions of soil and climate (dry and cold, for instance), applications of chlorates may not reach a maximum efficiency until warm, moist weather sets in. Hulbert, Rembsberg, and Spence (56) agree in this regard. They found that the full effectiveness of a chlorate weed treatment was not manifested until the following season. They recommend that chlorate-treated areas not be irrigated and state that complete destruction of weeds does not follow with sufficient regularity to support the belief that single applications of chlorates are ample and generally satisfactory. This finding is general and quite common.

In his experiment with Johnson grass *(Sorghum halepense)*, Harper (51), as did Walker (115), found 2 or 3 sprays necessary to eradicate the pest. Harper also

stipulates that when Johnson grass may be cut with a mower, the first stand should be mowed when incipient heading occurs; then follow with the spray after the ratoon reaches a height of 12 to 18 inches.

Aftereffects of Chlorates on Crops, Soils, Humans and Animals:

Most experimenters agree that chlorates sterilize the soil to a greater or less extent, but there is little unanimity among observers regarding the duration of the sterilization. The reason for this wide divergence in opinion is no doubt due to the fact that observations are sometimes made and recorded without correlating in greater detail climate and weather or moisture and organic relationships in the soil.

Bickmore (17) states that chlorates are decomposed in soil during the winter and as a consequence do not affect the following spring plantings or the subsequent crops. This statement might be made more specific if it included data upon snow and rains in winter, warmth in early spring and porosity of the soil.

Crafts (34) found that continual leaching of the soil with irrigation water was the best method extant of clearing land of residual sodium chlorate. In his experience, areas which had become sterile as a result of chlorate weeding practice 3 years previously were returned to productivity by leaching them with 36 inches of water. This accomplishment was made within a single season. (Open, porous soil is assumed, of course.)

Crafts (34) differentiated between soil types in noting toxicity effects of chlorate applications. He found toxicity highest in an adobe and lowest in a clay, but 40 cm. of water was sufficient to remove the chlorates by percolation, from the clay soil. He found much less fixation of chlorates than of arsenic in four soils which were studied.

As to the toxic effect of chlorates, an examination of the structural formulae of sodium chlorate, as an example, reveals two loosely combined oxygen atoms with double bonds ($Na - O - Cl\overset{=O}{\underset{=O}{}}$). This structure denotes instability, particularly in the presence of organic or other reducing matter. Upon reduction of the chlorate, nascent oxygen is released. Apparently this active oxygen is the component of the chemical which destroys plant life, weed or otherwise, for Aslander (4) states that probably oxygen attacks the sensitive part of plant protoplasm and, by inference, is responsible for its collapse. One type of compound which should arrest the toxic action of a chlorate in the soil and thereby assist in reclamation of the soil would chemically be opposite in character to the oxidizing chlorate, i.e., a reducing agent.

It is interesting to find the record of a patent granted Ehrhardt (38) for a number of soil reconditioning processes to be used following a soil chlorate-weeding application. Among the compounds he describes are ferrous salts, hyposulfites, and nitrites. Another type of soil reconditioner for chlorate damage is set forth in this patent as a substance which accelerates catalytically the decomposition of residual chlorates. Magnesium chloride is an example of reconditioners of this character.

Anent the toxicity in the soil of chlorates there is reason to believe, in some open soil types, that weak solutions of chlorates may be used regularly and with impunity. Woodman (119) reports that wheat has been sown safely without ill effects after spraying a field area with one per cent sodium chlorate. (This is about one-tenth

the concentration usually used.) But with solutions of higher chlorate concentration, he states that sowing should be left until the following season, *depending on the nature of the soil and climatic conditions.* Any one of the negative dependent conditions would justify jumping a season, no doubt, such as a tight soil, cool weather or scant rainfall.

Shear (96) found that the growth of mushrooms was enhanced on plots in which sodium chlorate was used to destroy quack grass *(Agropyron repens).* Comparison was made on a similar area of untreated soil. He speculates on the cause, suggesting that lack of competition, increased available food materials or direct chlorate stimulation may have accounted for the increased mushroom growth. This published experience has been the only one encountered where a possible direct benefit to plant development has been suggested as due, possibly, to a chlorate.

Loomis, Smith, et al (73) have found that chlorates, whether applied direct to the soil or reaching the ground from sprayed plants, remained unchanged for a period of 2½ years. Statements such as this are frequently met. These investigators add that removal of chlorates from the soil by leaching requires large quantities of water. They are inclined, from their observations, to ascribe decomposition of chlorates as the principal method of their becoming non-toxic in soils (not by leaching) and have found decomposition to take place with fair rapidity in moist soil at temperatures above 20° C. A statement appears in a circular by Arny, Bridgford and Dunham (3) to the effect that in Minnesota, when about 500 pounds per acre of chlorates are applied to the soil, sterile conditions remain in that region from 7 months to a year or longer.

In contact with the skin, chlorates do not appear to be harmful to humans and when consumed by grazing animals on sprayed vegetation, they do not, it seems, occasion any injurious results. Megee and Hudson (78) state that sheep were grazed without ill effects upon meadows recently sprayed with sodium chlorate. Latshaw and Zahnley (69) support this observation for they appear also to have found sodium chlorate non-poisonous to livestock which had grazed on chlorate-treated vegetation.

Apparent contradictions to these findings may be found, but it should be emphasized that, as a rule, where chlorates are reported as harmless to stock, it is *after* applications of the chemicals to weeds or grass. Destruction of weeds by chlorate sprays undoubtedly decreases the potency of the chlorates in the process and leaves a saline residue containing little, but, nevertheless, some of the original chemical. Given directly to animals, Seddon and McGrath (95) report 2 to 3 ounces of sodium chlorate as fatal to sheep within 24 hours and ⅔ ounce of the same chemical, consumed by a steer daily for about 2 weeks, was fatal to this animal. In these cases the animals took the chlorates directly into their systems and not after the chemical had acted on vegetable matter.

The Fire Hazards of Chlorates:

An undecomposed residue of dry chlorate in fine division and distributed over a large area of dry or dead weeds or grass is unquestionably a serious and real fire hazard. Conditions of partial dryness may be more hazardous. In the former case but a spark is needed to set off the entire area in a fierce blaze. In the latter case,

under favorable combustion conditions, a fire may break out spontaneously. Either type of fire may occur a few days after a chlorate weed spraying for the conditions necessary to favor either set of circumstances may easily develop.

It is a matter of record that really disastrous fires of such a nature have seldom been reported.

The chemical similarity of chlorates (in intimate contact with dry plant material) to gun powder (chlorate of potash and charcoal) has been recognized by investigators of herbicides and measures have been developed to reduce this hazard. Unfortunately this danger is not confined to dead weeds and grasses. Chlorate solutions, even when modified to reduce the field fire hazard, are dangerous in the extreme when spilled on the worker's clothing or upon combustible materials in warehouses and sheds. In both cases chlorates may accumulate by repeated and successive spillings. The warmth of a man's body, with exposure to sun and wind, may readily drive out the protective moisture of the calcium chloride or other moisture-absorbing agent placed in the spraying compound to reduce the fire hazard in the field. Under conditions such as these, a spark or match flare may envelop in flames a garment which has previously been moistened with a chlorate solution. In the case of the chlorate-soaked refuse in warehouse or shed, spontaneous combustion is definitely invited.

Therefore, it is significant to find, in the published works of research investigators studying chlorates, repeated warnings to others to avoid spilling the chlorate solutions on the clothing or on refuse. The chlorides of calcium or magnesium are usually added to chlorate spray solutions to reduce the fire hazard after application of the spray by the ability these compounds possess for absorbing and retaining moisture, even from the open air on a clear dry day. Bickmore (17) states that equal quantities of a chlorate and of calcium chloride, or ⅓ by weight of magnesium chloride and ⅔ by weight of a chlorate, render the mixtures safe as far as fire in the sprayed area is concerned. These additions reduce the herbicidal action of the chlorate, however.

It has been found that broadcasting dry chlorates materially reduces the fire hazard as compared with the more evenly distributed chemical in fine division on weeds dried out after spraying. Gray (44) states that the dry chlorate application, when made with due precaution, eliminates the fire risk which accompanies the use of chlorate solutions.

In a study made by Cook (29) on the combustibility of organic matter and chlorates in various proportions at different relative humidities, he determined that mixtures containing more than 10 per cent sodium chlorate are hazardous below 75 per cent relative humidity. Also that admixtures of calcium chloride or magnesium chloride with sodium chlorate render the mixture safe when these moisture-absorbing salts form ½ to ⅓, respectively, of the resulting herbicide. Furthermore, he states that the sodium chlorate-magnesium chloride mixture is the most effective "safe" herbicide, but it is only about half as efficient in weed-destroying ability as pure sodium chlorate.

The author (50) has found that additions of sodium stannate or sodium phosphate to sodium chlorate solutions also reduce the fire hazard of these sprays.

Summarizing the Discussion on Chlorates:

Applications of chlorates: As a spray for general purposes, dissolve one pound of sodium chlorate and one pound of calcium chloride in sufficient water to make one gallon of finished solution. Apply 150 to 200 gallons of the solution per acre, then repeat the treatment twice at intervals of about 3 weeks.

As a dry application, broadcast a mixture of 12 pounds sodium chlorate and 100 pounds powdered dry sand, limestone or raw rock phosphate. Use 5 pounds of the mixture per 10 square yards of weed carpet.

Effectiveness of chlorates: There is ample evidence to support the statement that sodium chlorate (one pound per gallon in water solution) brought in contact with the weed root system and used at the same time to saturate the foliage will destroy that plant. Any less thorough application may or may not partially or entirely incapacitate the weed or suspend its growth for an indefinite period.

Aftereffects of chlorates on crops, soils, humans and animals: After application to vegetation (weeds, grasses, etc.) chlorates do not seriously injure stock which may thereafter graze on the treated plants. Aston and Bruce (6) state that fatal burnings of human beings have been recorded as a result of using sodium chlorate sprays. Chlorates applied to soil definitely sterilize that soil for periods which may vary from a few weeks to a few years. The duration of sterilization should be least for any given quantity of chlorate in an open porous soil containing organic matter, subject to heavy rainfall or frequent irrigation in a warm climate.

The fire hazards of chlorates: Undecomposed chlorates on dead weeds in dry sunny weather constitute a serious fire hazard. Accumulation of chlorates on clothing are dangerous. Spilled on refuse or in contact with any combustible material, chlorates may decompose and supply oxygen in quantities sufficient to start spontaneous combustion.

Chlorates used in weed control are protected against fire risk in the field by including in the spray solution as much as an equal weight of calcium chloride per weight of sodium chlorate used. This protection reduces the tendency for a loss of moisture to take place in dead weeds to a point of tinder dryness. It does not prevent spontaneous combustion in combustible material situated in poorly ventilated places.

Oil Sprays

A great number of oils have been used in weed control, but of these the most effective (cost considered) appears to be Diesel oil. Oils destroy weeds by contact and, although they are absorbed by weed tissues more readily than are aqueous herbicides, they do not always destroy the weed roots. However, as a class, oils are one of the few substances commonly used which do render weed seeds impotent.

Two of the outstanding advantages of using Diesel oil for weed control on plantation railroad right-of-ways may be stated as: (a) the oil is harmless to the rails; and (b) at the same time it is beneficial to the ties.

In Hawaii, Diesel oil has been used extensively by several plantations and in experimental weed control by Denison (37) at rates of 100 to 300 gallons per acre. Denison found the application of 155 gallons per acre on shorn weeds more effective than 275 gallons applied to larger and heavier growths. The extra cost of Diesel oil, compared to other sprays, was offset by the reduced costs of labor in covering the

same area by non-poisonous sprays. In general, oils cannot compare with arsenicals, either in cost or in effectiveness, for weed control. When purchased for weeding practices, Diesel oil should meet the specifications submitted by Normann (85) in a report on the subject which occupies the entire issue of the February 1937 number of *Public Roads*. His specifications follow:

Specific gravity (A.P.I.) at 60° F.—not less than 27° Baumé.
Flash point (Penskey-Martin closed cup)—not less than 150° F.
Viscosity (Saybolt Univ.) 100° F.—not over 50 seconds.
Distillation (90 percent point)—not over 680° F.
Water and sediment—not more than a trace.

Oil emulsions have been found quite satisfactory in California.

Johnson (64) states that a Diesel oil containing 2½ per cent of asphalt will emulsify readily with water and that this emulsion penetrates and destroys the weed seed burrs.

Less Common Weed Eradicants

A brief description follows of some of the less frequently used chemical compounds in weed control.

Ammonium Sulfate:

(Quotation: $35.43 per ton, f.o.b. Honolulu)

Ammonium sulfate $(NH_4)_2SO_4$, is a white or pale-yellow granular salt freely soluble in water. It forms a water solution which is acid to litmus paper. It reacts chemically with lime and alkalies, liberating free ammonia. It produces, at first, a temporary acidity when applied to the soil. This induced soil acidity is rapidly dissipated unless frequent or recurrent additions of the chemical are made. The eventual effect of long-time applications of sulfate of ammonia to the soil is said to bring about a loss of soil bases and a permanent increase of soil acidity.

Sulfate of ammonia is used extensively as a fertilizer and as a constituent in compounds used to repel flames or fires. The purified chemical does not cake in storage, but in a confined space it liberates ammonia in small amounts. Applied to the soil it exerts a toxic action to common weed growth, but at the same time it stimulates and fertilizes grasses of all kinds (including sugar cane). Its purchase price is governed by the market value of its nitrogen fraction.

One hundred to 400 pounds per acre, applied in dilute solution or dry-mixed with sand or other carriers, will tend to reduce weeds in lawns and greens.

According to Blackman (19), occasional applications of sulfate of ammonia on grass plots not only reduced the weeds but did so without producing a significant change in soil reaction—an important consideration already referred to above and again below.

When applied at the rate of about 130 pounds per acre every two weeks during spring and summer, Blackman (18) states, in another paper, that this treatment diminishes the weeds and increases the area covered by grasses. He states that soil acidity is not a prerequisite for weed reduction by sulfate of ammonia, the toxic effect probably resulting from the differential action of ammonium ions, which are toxic to most species of weeds, whereas they increase the growth of grasses. He

also observed that equivalent mixtures of ferrous sulfate and ammonium sulfate produced a greater reduction in weeds than did sulfate of ammonia alone.

Long (72) advocates the use of lawn dressings consisting of 3 parts sulfate of ammonia, one part calcined sulfate of iron and 20 parts sand. The mixture should be spread at intervals of 2 weeks during growing season at the rate of ½ pound per square yard. He states that this mixture is very effective in reducing broad-leaved species of weeds. As a fertilizer on lawns it is excellent.

Jaquenaud (62) found that very dry and finely powdered sulfate of ammonia acts as a strong herbicide when used at the rate of 300 to 400 kilograms per hectare (about the same figure in pounds per acre). He says that it is too active for use with cereals, but that its severity can be reduced by diluting 2½ parts of ammonium sulfate with an equal quantity of sylvite (native potassium chloride) and 1½ parts of finely ground (rock) phosphate.

Ammonium Persulfate:

(Quotation: in kegs, 21¢ a pound, f.o.b. New York)

Ammonium persulfate $(NH_4)_2S_2O_8$ is a white, crystalline substance. In closed containers, protected from sunlight, it will keep for years unchanged. Exposed to light, air and moisture in contact with organic substances (plants and weeds), it decomposes the plant material by charring but does so without danger of causing fire. It is a powerful oxidizing agent, being similar in this respect to sodium chlorate. It is very soluble in water, the solution so formed slowly decomposing and giving off "ozonized oxygen." Its toxic effect upon vegetation is due to its oxidizing and to its charring properties.

In a circular issued at the University Farm in St. Paul, Harvey (52) reports the results of a preliminary study of this chemical. It appeared to have a more potent action on some weeds than did ammonium sulphocyanate. Pound per pound, it was equivalent to sodium chlorate in weed-destructive action. It appears to decompose in the soil and thereby yield nitrogen and sulphur as fertilizer. It has the disadvantage, however, of attacking brass, copper, iron and zinc. It does not affect rubber or aluminum.

Ammonium Thiocyanate (also called Ammonium Sulphocyanate):

Ammonium thiocyanate, $CNS(NH_4)$, occurs in gas liquor and in crude coke-oven by-product liquor. It is also formed by heating a mixture of carbon disulphide, concentrated ammonia and alcohol. It crystallizes in colorless plates soluble in alcohol and in water. It is unstable in the presence of organic matter, contact with which causes it to break down into simpler products. Its value as a fertilizer is questionable when considered upon a cost basis of the commercial chemical. As a constituent of "gas liquor" its cost is materially reduced.

This compound is another dual-purpose weed eradicant. Claims are made by some experimenters that it supplies nitrogen and sulphur after it kills weeds and is itself decomposed and rendered non-toxic in the process. Harvey (52) states that its harmful action on vegetation, other than its action by contact with weeds, is destroyed by soil bacteria. He recommends that from 320 to 480 pounds be applied

per acre in solution at intervals of from 4 to 6 weeks. He stated in a later paper (53) that its toxic action is less persistent in the soil than that produced when chlorates are used. Toxicity disappears in 3 months after an 800-pound application and in one month following a 320-pound application. It appeared to stimulate desirable plant growth after its toxic action subsided.

Unlike chlorates, Harvey states that it is not explosive when mixed with organic materials. As a weed eradicant, it tends to keep the dead plants moist until it is leached off by rain.

Its disadvantages are its cost (about 20 cents a pound) and its corrosive action on metals and leather. It does not attack rubber.

Aston, Bruce and Thompson (8) report results similar to Harvey's. They found a dry mixture of ammonium sulphocyanate one part, with super phosphate 3 parts, effective in the control of unmowed ragwort *(Senecio sp.)* at the rate of 400 pounds per acre. Referring to the claims made that these cyanates function as fertilizers in addition to killing weeds, Skinner and Sandhoff (97) found that only half of the nitrogen of ammonium thiocyanate can be considered as available fertilizer.

Experimenters with thiocyanates frequently recommend that, when it is obtainable, a by-product crude liquor containing this chemical be used in preference. This thiocyanate liquor also contains tarry residues. Its effectiveness in weed control is said by Long (72) and others to be superior to solutions of the chemical alone. Stock will not graze on vegetation sprayed with thiocyanates because of the unpleasant taste. Ball, et al (12), state that ammonium thiocyanate is ineffective in California. Its use in Hawaii has been disappointing.

Borax (Sodium Borate):

(Quotation: tech. cryst., $56 to $67 a ton, delivered)

Borax, or sodium borate, is a white, gritty, granular substance which is refined from natural deposits occurring in dry inland lake beds of California and other places throughout the world. Borax is not freely soluble in water. Less than 2 per cent can be dissolved at 50° F. It forms a mildly alkaline solution in water, a property which renders it satisfactory as a gentle detergent.

Borax is used extensively in industry and in the arts, but its effect on plant life is frequently toxic, even in small quantities. In minute amounts, borates have been found essential for the normal growth of a number of plants.

Because of comparatively low solubility, borates are used as dry applications in weed control. Ball, et al (11), state that borax and borate ores are cheaper and more persistent in effect than are chlorates. A combination of one part of sodium chlorate and 8 parts of borax applied dry at 4 to 16 pounds per square rod makes a satisfactory weed eradicant, according to these investigators. Users are warned that borates are dangerous compounds to use on citrus fruits, deciduous fruits, grapes, nuts and certain ornamentals.

Calcium Cyanamide:

(Quotation: 21-22 per cent N, pulverized, in bags, $1.15 per NH_3 unit)

Calcium cyanamide, CaNCN, is prepared by heating calcium carbide and nitrogen to a temperature of 1100° C. It is a dark gray, granular substance which dissolves

in water, forming dicyandiamide, a product which decomposes readily in the soil, yielding the elements of ammonia.

Calcium cyanamide is another compound used in weed control which contains plant nutrients as its principal constituents. This product is a commonly used nitrogenous fertilizer. It has distinct weed-inhibiting properties and crop recovery is, as a rule, positive and rapid. About 60 per cent of the weight of calcium cyanamide is essentially active lime and hence its use on soils low in calcium may be quite beneficial. It contains about 21 per cent nitrogen; thus, it is comparable to sulfate of ammonia on a nitrogen basis. It has the advantage over sulfate of ammonia in not contributing to increased soil acidity nor to the loss of desirable soil bases. Applied dry, either powdered or granulated, at the rate of 500 pounds per acre when weeds were 1½ inches high, Smock (99) states that it effectively controlled annual weeds throughout the cutting season.

Calcium cyanamide appears to be very effective in the control of weeds on lawns and golf greens. Sturkie (105) treated a badly weed-infested Bermuda grass *(Cynodon dactylon)* green with this chemical by application of 800 pounds per acre on the dormant grass. The weeds were killed and the nitrogen added stimulated the later growth of grass. On a lawn of various perennial grasses, he destroyed the weeds by applying 1000 pounds or more of the cyanamide and noted that while the grass was seriously burned, it soon recovered and grew vigorously.

In larger scale chemical weeding operations, calcium cyanamide has been used with a fair degree of success. Korsmo (68) describes the dusting of weedy cereals with this compound when they were covered with dew. The treatment was beneficial to the grain and reduced weeds about 75 per cent.

Jaquenaud (61) describes a powdered weeding mixture which consists of cyanamide, sylvite (native chloride of potash) and sulfate of ammonia. Incidentally, this mixture is a complete fertilizer.

Carbon Bisulphide (Carbon Disulphide):

(Quotation: in 55-gal. drums, $0.05 a pound, f.o.b. New York)

Carbon bisulphide, CS_2, is a volatile, explosive, foul-smelling liquid which may be produced by passing sulfur vapor over red-hot charcoal. Carbon bisulphide boils at 46° C., a few degrees higher than body temperature. Its vapor is 2⅔ times heavier than air; when mixed with air, it is highly and violently explosive. When breathed in small quantities over a period of time it is injurious to health. If taken into the lungs not sufficiently diluted with air, its action is fatal.

Carbon bisulphide is employed for weeding purposes in very difficult stands of persistent perennial weed pests in small areas or where cost and hazard may not forbid its use.

It is very inflammable, entails heavy loss by evaporation, and is expensive.

When used properly, carbon bisulphide completely destroys the weeds it contacts. Ball, et al (11) describe a carbon bisulphide weeding procedure whereby holes are made in the soil 18 inches apart each way in staggered rows over an infested area to be treated. Two to four ounces of the chemical are poured in each hole. The depth of the application is important. If there is ample moisture in the surface soil, the application should not go below 6 inches. If the surface soil is dry, it will have

to be placed at a lower depth, but if it is placed too low, the vapor of the chemical (being much heavier than air) may not contact the root crowns in sufficient concentration to destroy them. In any case, immediately after pouring the chemical, the holes should be filled with moist soil and carefully tamped. Complete diffusion of carbon bisulphide will take place in the treated soil in about 3 to 6 weeks. After this period the soil will be found unaffected for subsequent crops. This is an expensive but a very effective method for eradication of guava *(Psidium guayava)*, lantana *(Lantana camara)*, gorse *(Ulex europaeus)*, etc.

As an illustration of the unusually effective herbicidal properties of this chemical, Ball and Robbins (13) report that the very obnoxious and difficultly eradicated camel thorn *(Alhagi camelorum)* (in California) can be destroyed by carbon bisulphide with a thorough treatment of the soil to a depth of 10 inches.

Rodgers and Hatfield (92) applied the chemical in holes 12 to 18 inches deep, 2 feet apart, in controlling other perennial weeds of persistent characteristics.

Copper Sulfate:

(Quotation: 99 per cent cryst., in barrels, $5.00 per 100 pounds, f.o.b. New York)

Copper sulfate, $CuSO_4.5H_2O$ is the "bluestone" of commerce. It may be prepared by dissolving copper metal in sulfuric acid, blue crystals separating out on cooling. It is readily soluble in water, forming a weakly acidulated solution.

The toxic action of bluestone on certain vegetation is a mild but effective one when its water solution is applied properly diluted. It is used commonly to destroy algae and similar plants in reservoirs, ponds and even in fish aquariums. It is not used to any great extent in large areas but Long (72) states that cereal crops are rarely damaged by sprays containing 3 to 5 per cent of copper sulfate, 40 to 100 gallons per acre. He notes that a temporary check may be given the cereal. The same observation applies to peas, beans, and vetches when so treated, but they recover satisfactorily from any preliminary injury.

In experimental weed eradication on garden paths at Craibstone in Scotland, Hill (55) applied one pound of powdered copper sulfate per 100 square feet with an additional one per cent solution of sodium chlorate. It gave good results, but the efficiency of both compounds decreased with increased rainfall during the first week of applications. A mixture consisting of one part of copper sulfate and 3 parts of concentrated sulfuric acid (60° Bé.) has been patented in England by Litsche (71) as a material recommended for the destruction of weeds in growing crops.

In a report of the Nova Scotia Department of Agriculture (86) the statement is made that a 3 per cent solution of copper sulfate applied as a spray upon grain when it was approximately 4 inches high gave excellent control of cadlock *(Brassica arvensis)*.

Dyes:

Claims are made by Truffaut and Pastac (110) that certain organic dyes in water solution are destructive to plants and weeds. Unsulphurated acid dyes exert a marked action on herbaceous plants which varies with age and nature of plants, the amount of dye used and the wetting power of the solution. Wild mustard *(Brassica*

arvensis) or thistle *(Circium arvense)* can be destroyed in wheat and oat fields, using a properly prepared dye solution, without injury to the cereals. Similarly, certain weeds in lawns may be destroyed.

Iron Sulfate (Copperas—Green Vitriol):

(Quotation: cryst., gran., in barrels, $16.00 to $17.00 per ton, works)

Ferrous sulfate, $FeSO_4.7H_2O$ is a pale-green, glass-like crystalline compound which may be prepared by dissolving scrap iron in sulfuric acid. It dissolves in water, forming an acid solution which is rapidly decomposed by the oxygen of the air.

Aslander (5) reports that ferrous sulphate solutions were effective at high relative humidity in killing wild mustard. At low humidity, little injury was noted. He adds that ferrous sulphate destroys plants by direct chemical action and not in withdrawal of water from plant tissue by plasmolysis.

Applied to weed-infested cereals at a concentration of 15 to 25 per cent, about 300 gallons per decare (1200 gallons per acre) when weeds and cereal were small, weeds were reduced about 80 per cent and the grain (oats) was increased about 25 per cent. Wild mustard *(Brassica arvensis)* was destroyed in fields of oats or barley by Viger (113) without great injury to the grain by spraying the weeds with a 20 per cent solution of ferrous sulfate, 100 pounds of the chemical per acre.

Normann (85) states that grasses and grain are very resistant to ferrous sulfate spray and although it causes them to become black when first sprayed they soon recover. He adds that the spray is most effective when applied on humid days when rain is not likely to fall. Rain, he says, washes off the solution and in very dry weather the solution may evaporate from the sprayed weeds, leaving a residue which falls off the leaves before they are affected. Evidently ferrous sulfate is not a generally satisfactory herbicide. It has the added disadvantage of discoloring buildings, walks and clothing. However, it is very effective in the destruction of garden snails and slugs.

Kainite:

Kainite, $K_2SO_4.MgSO_4.MgCl_26H_2O$, is a naturally occurring fertilizer having weed-destructive properties. It contains approximately 35 per cent potassium sulfate, 24 per cent magnesium sulfate and 19 per cent magnesium chloride.

It has been used satisfactorily to combat weeds upon areas low in potash. It appears to have the ability to withdraw moisture from the inner tissue of the weed plant.

Long (72) places its practical limits of application at from 400 to 800 pounds per acre applied in warm, dry weather, early in the morning, upon weeds wet with dew. As a weed killer and a fertilizer it may be applied dry as a mixture of 5 parts kainite with one of cyanamide at the rate of 500 to 600 pounds of mixture per acre. Long has found this application very satisfactory.

Demela and Brada (36) report that an application of 550 pounds of finely ground kainite and 135 pounds of calcium cyanamide per acre was effective for 2 years against a number of common weeds. Husemann (59) experimented with

kainite, using very finely powdered dusts. He also studied the effects upon weeds of using kainite having a high or a low chloride concentration. He found that increases in fineness reduced the tendency of the dust to form aggregates and, as the chloride fraction of the compound increased, its herbicidal action was improved.

Sturber (104) described a long-time effect of kainite in destroying weed growth in which a plot treated in 1927 with 1071 pounds of kainite per acre (in fine powder) to destroy charlock *(Brassica arvensis)* in oats remained clear of the weed when oats were again grown in the same plot in 1932. A control of weeds which infested cereal on a moss peat soil was obtained by Brune, Husemann, et al (25) by the application of from 150 to 650 pounds of kainite per acre 4 to 5 weeks after sowing the summer crop or about the middle of November with the winter crop.

Butler (26) has found that one pound of kainite per 10 square feet of poison ivy *(Rhus toxicodendron),* dusted on the wet foliage, is usually sufficient to kill this pest. Complete eradication may be obtained by applying a second or a third application.

Sodium Bisulphate (Nitercake):

(Quotation: in bulk, $16.00 per ton, works)

Sodium bisulphate, $NaHSO_4$, is an acid salt, soluble in water. It is prepared by heating sodium sulfate with sulfuric acid and allowing the mixture to cool, whereupon the acid sulfate crystallizes out. This compound attacks common metals. Its use in the laboratory is confined chiefly to the removal of fused metallic oxide residues from platinum apparatus.

Long (72), in his text on chemical weed control, credits French with having learned that 20 per cent solutions of sodium bisulphate will destroy charlock *(Brassica arvensis)* in cereals at all stages of growth. On very heavy growths of weeds, an application of 350 pounds of sodium bisulphate per acre has been made in a 45 per cent solution. Long notes that bisulphates have been found effective in controlling aquatic weeds.

Sodium Bisulfite:

(Quotation: powdered, in barrels, $3.35 to $3.60 per 100 pounds)

Sodium bisulfite, $NaHSO_3$, is an acid salt of sulphurous acid. It attacks plant materials because of the ease with which it becomes decomposed, liberating, at the same time, free sulphurous acid vapor. It is used extensively in bleaching.

Aston and Bruce (6) and Kolzov (67) report that satisfactory eradication of weeds may be accomplished using dusts or solutions of sodium bisulfite on lawns, gardens and paths.

Aston, Bruce and Thompson (8) describe comparative experiments carried out with sodium bisulfite, potassium bisulfite and sodium-ammonium bisulfite for control of ragwort *(Senecio sp.).* In some instances the weed was completely eliminated, using 10 per cent solution of either the sodium or potassium compounds. In other cases, weed-destroying properties were feeble. Applied on lawn weeds, grass was temporarily affected, but soon recovered.

Sulfuric Acid:

(Quotation: in carboys, $1.25 to $1.50 per 100 pounds)

This chemical has been used extensively in Europe for weed control. Its use in America for the same purpose has become much more general during the past few years. Sulfuric acid is supplied by the manufacturer usually in glass carboys in concentrated form (60° Bé. to 66° Bé.). More concentrated acid may be shipped in steel tank cars or steel drums at weather temperatures above freezing.

Any concentrated form of the acid is a heavy, oily liquid which will severely burn a person or his clothing, will corrode all base metals except steel and will destroy rubber. When water is *added to* concentrated sulfuric acid, it will combine chemically with explosive violence. Highly diluted sulfuric acid attacks all common metals including steel and iron, but it does not affect rubber nor is it critically dangerous when spilled on the body or on clothing.

Brought in contact with any common organic substance, sulfuric acid will decompose that substance by charring and in the reaction release and absorb the "elements of water" (hydrogen and oxygen) which the substance may contain. In spite of its dangerous chemical properties it is a substance not difficult to handle or manipulate, providing two important precautions are observed: (a) Never allow the concentrated acid to come in contact with any part of the body or clothing, and (b) in diluting this acid always add the concentrated liquid acid in a slow stream *to* a large volume of water, stirring constantly. The diluted acid attacks the metal of weed-spraying equipment. It is a very active herbicide toward shallow-rooted annual weeds. It is less effective on grasses and deep-rooted perennials, but does check their growth.

Its mild destructive action on grasses and cereals suggests its experimental study as a herbicide in sugar cane fields.

Long (72) states that 7 per cent to 10 per cent solutions of crude sulfuric acid in water are effective against a great variety of annual and biennial weeds. He regulates the time of spraying with age of weeds and crop—4-leaf stage in charlock *(Brassica arvensis)*, for instance, in cereal 3 to 7 inches high. He advises the user to spray during dry weather, but states that it is no disadvantage to apply the solution to weeds covered with dew and even a light rain on the day following the application will not seriously affect the results which are sought. He states further that all cereals (and perhaps sugar cane) may be sprayed with safety and that any slight browning which results will most likely rapidly disappear. Also that the soil is in no sense injured by the small quantity of uncombined acid which may fall to the ground.

Ball (11) and his co-workers support the conclusions of Long which have just been enumerated. They have also used a sulfuric acid solution, 10 per cent in strength, with entire satisfaction in the control of a number of annual weeds in grain fields at the rate of 130 gallons of 10 per cent solution per acre. They observed marked increases in grain yields following this acid treatment of field weeds. They list the advantages of sulfuric acid sprays as:

(a) Economical, costing one cent for one gallon of 10 per cent solution.

(b) Neither poisonous to stock nor combustible.

(c) Decomposes weed tissue very quickly.

(d) Are not detrimental to the soil.

Blackman and Templeman (21) have employed 9.2 per cent solutions of the acid in control of yellow charlock *(Brassica alba)* and the relatively high concentration of 13.8 per cent acid in a 95 per cent control of white charlock *(Raphanus raphanistrum)*. In both cases higher yields of cereal were obtained as compared with no acid treatment. It has been their experience that dilute sulfuric acid does not normally depress crop yields although in very dry weather some damage may occur.

MacDowall (74) secured a 70 per cent kill of white charlock *(Raphanus raphanistrum)* using an 8 per cent solution of sulfuric acid, 100 gallons per acre of barley. Using 75 gallons per acre of a 10 per cent solution, a 90 per cent kill of yellow charlock *(Brassica alba)* was realized. The barley wilted during the 24-hour period following the spraying (it was 4 to 6 inches high when the spray was applied), but it gradually recovered, he stated, and 18 to 20 days later it was much greener and more vigorous than similarly established unsprayed portions. Maturity was delayed 8 days by the treatment, but there was an estimated gain in the yield of grain of 20 per cent over the unsprayed portions. Not including overhead and other usual items of expense, the cost of the spraying per acre was about 10 shillings ($2.50).

In summarizing his research using dilute sulfuric acid in weed control, Rabate (89) states that during a period of several years his experiences indicate that this acid acts as a fertilizer of the soil, destroys many weeds and many crop parasites. As to the fertilizer value of sulfuric acid in the soil, its virtue in this sense, it would seem, may be related to the solvent action it may have upon available nutrient or even to a lesser extent upon organic constituents of the soil. Braun (22) states a contrary opinion in this connection for he has found weeding treatments of grain with dilute sulfuric acid not to have any appreciable dissolving action in the soil upon the three principal nutrient elements. The fact remains, however, that very dilute sulfuric acid is commonly used in laboratories as a solvent of available soil nutrients, particularly phosphates.

Brown and Streets (24) report satisfactory and practical usage of dilute sulfuric acid in weed control. They used 2 per cent solutions for pig weed *(Amaranthus spp.)*, wild mustard *(Brassica arvensis)*, etc., and in increased concentrations of 5 per cent and 8 per cent for some of the hardier weeds such as sow thistle *(Sonchus oleraceus)*, nettle *(Urtica gracilis)*, golden rod *(Solidago sp.)*, Bermuda grass *(Cynodon dactylon)*, foxtail *(Setariaverticillata)* and from 10 per cent to 15 per cent for an out-and-out kill of Johnson grass *(Sorghum halepense)* and nut grass *(Cyperus rotundus)*.

To avoid excessive corrosion of the metal parts of spraying equipment (they found any type satisfactory) the apparatus was coated with cylinder oil or cup grease before placing them in service.

While most investigators are inclined to favor the use of sulfuric acid weed sprays, Barbut (14) points out that one objection to this acid spray is that it is very active in deliming the soil.

Sundelin (106) found a 3½ per cent to 4 per cent solution of sulfuric acid, at the rate of about 100 to 135 gallons per acre, economical and effective as a control of weeds in spring cereals.

As a rule experimenters recommend that spraying with dilute sulfuric acid should take place when the crop (usually a cereal) and the weeds are both young and succulent. Blackman (20) noted diminished yields of both opal and Spratt-Archer barley when a 9.2 solution of sulfuric acid was applied in the later stages of the crop growth. However, in the third-leaf stage of Spratt-Archer barley, no damage to the crop growth nor to the malting quality of the barley was observed by the spraying of an 18.4 per cent solution of sulfuric acid. He reports a 94 to 98 per cent control of *Brassica sinapis* in clear weather, using a 9.8 per cent solution of sulfuric acid or 5 per cent solution of copper sulfate. When rain fell within 3 hours after spraying, the copper sulfate solution was ineffective but the efficiency of the acid spray was not decreased.

Few experimenters have commented on the precautions which they have taken to reduce corrosion of metal spraying apparatus when using this equipment for the application of dilute sulfuric acid. One exception noted has been Brown and Streets (24), who coat equipment with cylinder oil or cup grease before putting it in service. French and Ball (41) have made a study of equipment designed for this acid work. They recommend the use of an ejector with an ordinary spray pump to eliminate the corrosive effect of the acid on the working parts of the pump. They specify that all parts coming in contact with the acid must be of brass, but pure nickel or Monel metal, spray nozzle disks were found superior to brass. They state that a check valve should be placed in the pipe line on the suction side of the ejector.

Using this apparatus, they secured 96 per cent control of wild mustard *(Brassica arvensis)* in California barley fields using a solution of 10 per cent sulfuric acid by weight at the rate of 120 gallons per acre at a nozzle pressure of 75 pounds per square inch. The yield of barley in this experiment was increased 60 per cent.

In another publication, Ball and French (10) summarize their spraying technic as follows:

Preparation: 10 per cent by weight concentrated sulfuric acid in water solution.

Application: 130 gallons per acre.

Cost: Approximately $3.00 per acre.

Advantages: Sprayed plots produced 50 per cent more grain than unsprayed areas.

Zinc Sulfate:

(Quotation: cryst., in barrels, $3.30 to $4.00 per 100 pounds)

Zinc sulfate, $ZnSO_4$, is a mild acid and antiseptic having properties very similar to magnesium sulfate (Epsom salts). It is prepared by roasting zinc sulfide ore in air and extracting the clinker with water.

Westveld (116) at the Michigan Agricultural Experiment Station reports that about ⅓ ounce of zinc sulfate dissolved in ½ pint of water, when applied to one square foot of a white spruce seedbed, proved very effective in eradicating weeds (8 grams zinc sulfate in 250 cc. water).

Zinc Chlorate:

Refer to discussion under "Sodium and Other Chlorates."

Arsenicals

Compounds of arsenic are used very widely and extensively in chemical weed control in the United States and in other regions throughout the world.

Properties of White Arsenic:

White arsenic, As_2O_3, or more correctly, As_4O_6, arsenic trioxide (arsenious oxide), is a heavy, dense-white or light-gray powder as it appears in commerce. It will dissolve to some extent in water but with difficulty because of its naturally low solubility and also because of its characteristic property of repelling water and in not readily being made "wet" by water. It is easily soluble in hydrochloric and other acids, but is brought into solution quickly by hot aqueous solutions of the alkalies. The exact chemical composition of a solution of white arsenic in aqueous sodium hydroxide is a debatable matter. Compounds having the type formula $NaAsO_2$, Na_2HAsO_3, $Na_2H_4As_4O_9$, and others may be present. It is referred to commonly as sodium arsenite solution. It may be described as an alkaline solution of arsenious oxide or white arsenic. White arsenic reacts chemically as the anhydride of arsenious acid, H_3AsO_3 ($HAsO_2$ or $H_4As_2O_5$). Since it is a very weak acid, its reaction in equivalent quantities with the strong base sodium hydroxide, NaOH, forms a solution of alkaline reaction. It is possible, therefore, to prepare a highly concentrated or even saturated solution of white arsenic in aqueous sodium hydroxide and still obtain an alkaline solution.

In preparing a solution composed of white arsenic, caustic soda and water, an exothermic reaction or heat effect is produced. Within a wide range of variable amounts of these ingredients brought together, a violent evolution of heat takes place in their reaction. This property of heat evolution in the reaction of arsenic with caustic soda is made use of in preparing the so-called "self-boiling" and "self-stirring" concentrated stock solutions for dilution later as a spraying compound. White arsenic is also soluble in aqueous solutions of sodium carbonate and other mild alkaline mediums. In these cases solution is effected at a slow rate and without appreciable elevation of temperature. An alkaline solution of white arsenic may be neutralized with the addition of one of several mineral acids without precipitating the dissolved constituents. Such a solution may be rendered acidulous by adding more acid without impairing its stability.

The Effectiveness of Arsenic as a Herbicide:

Kennedy and Crafts (65) express the belief that arsenic is the most effective agent obtainable for general herbicidal purposes. Their criteria of herbicidal efficiency for any chemical warrant repeating. They state that effectiveness of herbicides depends, apparently, upon:

(a) Atmosphere and soil conditions which produce a water deficit in the weeds, thereby inducing a lowered pressure or suction within the plant xylem system.

(b) An exposure of the external weed surfaces to the destructive agent of sufficient duration to insure thorough absorption of the toxic solution.

Absorption of the toxic spray by the weed, they state, is probably influenced by insect injuries to the plant cuticle, by the surrounding temperature and moisture

conditions in plant and soil and by the death of cells within the plant which may render tissue more permeable.

They define the functions of the spray solution as: (a) creating a permeable entrance for the toxin to the xylem from the epidermis, and (b) as a lethal agent upon root tissue after the absorbed toxin has reached this region by translocation. Morgan (81) similarly defines the essentials for success in the use of herbicidal sprays. He states essentially: (a) that a good retention of herbicide on leaf surface is required, (b) that the spraying fluid should be capable of killing rapidly and of rendering the weed tissues permeable from cuticle to xylem, (c) that a pronounced water deficit within the xylem at the time of spraying is desirable so that extensive downward movement of herbicide will take place, and (d) that the herbicide should be highly toxic in order that the small volumes absorbed may be capable, in extremely dilute solution, of destroying a large bulk of tissue when lateral diffusion takes place.

Cost and convenience considered, dissolved arsenicals meet these requirements as well, if not better, than any chemical compound so far employed.

Sodium Arsenite:

This compound, of all the arsenicals, is used most commonly either as (a) a solution of the commercial chemical in water, (b) the so-called active constituent of spraying arsenicals prepared in the field, or (c) a dusting powder in combination with an inert carrier.

Adams (1) found a solution of 2 pounds of sodium arsenite in 52 gallons of water effective in reducing thistle *(Circium arvense)* and bracken *(Pteris aquilina)* in an area of one acre.

For treatment of annual weeds, Crafts (32) applied either to the top soil or to the vegetation a spray consisting of sodium arsenite solution at the rate of from 2 to 8 pounds of arsenite per square rod. He found the treatment effective.

As a treatment of wild bean *(Apios tuberosa)* in cranberry fields, Sawyer (93) describes a satisfactory experiment in which 10 pounds of sodium arsenite per acre, as an aqueous spray, completely killed the aerial portions of the wild bean.

Surber (107) reports success using commercial sodium arsenite in controlling submerged weeds in fish ponds. A very weak solution is used, it being equivalent to 2 parts per million of arsenic, or less, as AS_2O_3. He states that several applications may be needed per year and, as water hardness increases, it is necessary to increase the concentration of arsenic in the treatments. He found that natural fish foods were not impaired as a consequence.

In order to secure an efficient control of wild onion *(Allium canadense)*, Woodman and Jones (120) used up to 10 per cent concentrations of sodium arsenite, arsenic acid or any one of several chlorates. Of these, they found the arsenic compounds the most efficient.

Acidulated Solutions of Arsenic Compounds:

Crafts (31) states that if alkaline solutions of sodium arsenate are acidified with sulfuric acid before application to weeds, the percentage kill is greater and, in addition, no permanent injury results in the crop-bearing power of the soil.

Robbins (91) likewise recommends an acid arsenical spray for weed control. He states that concentration of approximately 0.5 per cent As_2O_3 in the acid spray are as effective against weeds as higher concentrations and that 20 pounds of arsenious oxide in this type of solution is all that is required for application to one acre of morning glory.

Morgan (80) also favors the acid arsenical spray and states that it gives very satisfactory control of hoary cress *(Lepidium draba)*. He cites an interesting measurement of the translocation of the arsenical in the weed tissue 0.4 per cent As_2O_3 and 5 per cent H_2SO_4, finding the rate of movement of the arsenical solution downward through the tissue of hoary cress as 0.5 inches per second under field conditions and in morning glory *(Convolvulus arvensis)* a maximum rate of 2.5 inches per second.

Crafts (31) reports that 0.5 per cent As_2O_3 was the lowest concentration of arsenic in an acid spray solution which gave effective control. The corresponding concentration of acid, i.e., the most effective one, was one part of free acid to 36 parts of water (one Normal).

Carn (27) describes a method of applying the acid arsenic spray to hoary cress. He stipulates that the spray should be applied in hot, dry weather, late in the day. On the following day the treated area should be sprayed with water. The weeds should not be disturbed by cultivation for some time before spraying and after this operation the area should not be cultivated nor grazed for some 6 or 8 weeks.

Comparison and Discussion of Formulae Published by Various Authors for the Preparation of the Acid Arsenical Spraying Solution:

Normann (85) and Carn (27) specify formulae which are identical. Normann gives credit to L. W. Kephart, senior agronomist, U. S. Department of Agriculture, for the method of preparing and applying the acid arsenical solution.

The Kephart-Normann-Carn formula:

Stir the following solution until dissolved—
White arsenic — 4 parts by weight.
Caustic soda — 1 part by weight.
Water — 2½ parts by weight.

When required for use, add 1 part by weight of the solution to 100 parts of water. After mixing thoroughly, add 5 parts by weight of a commercial grade of sulphuric acid slowly while stirring constantly.

Robbins (91) and Crafts (31) recommend a procedure which closely parallels that given above. It follows:

Robbins-Crafts formula:

"Preparation of stock solution: Mix (dry) 4 parts by weight of white arsenic (As_2O_3) and 1 part by weight of caustic soda (NaOH). Add 3 parts of water and stir until dissolved.

"Preparation of spray solution: Dilute 1 part of the stock arsenic solution with 100 parts of water. Mix thoroughly and add, with constant stirring, 5 parts by weight of concentrated sulfuric acid (H_2SO_4)."

An inspection of any of these formulae will reveal a very small quantity of water—a quantity which appears to be out of proportion with the other ingredients used. As a matter of fact, a clear, concentrated solution is not obtained in following directions outlined in either formula, but a very satisfactory *suspension* and solution of syrup-like consistency will be obtained.

Bertels and Elmanovich (15), in Russia, report their use of a spraying solution containing ten times the quantity of white arsenic (as used in the Kephart formula) for the destruction of vegetation on railroad right-of-ways. They claim that one liter of their spray solution, containing 5 per cent arsenic as As_2O_3, per square meter of roadway killed existing weeds with no recurrent growth during the remainder of the summer.

Arsenic Pentoxide (As_2O_5):

Unlike the more common and much cheaper white arsenic, As_2O_3, this oxide of the element As_2O_5 (also white) is readily and freely soluble in water, acids, alkalies and other solvents.

In spite of its higher cost, arsenic pentoxide has been used to a large extent in experimental weed control. It should be mentioned, however, that in addition to the increased expense involved in making field-scale use of arsenic pentoxide, there is a good reason to question its general effectiveness as compared to common white arsenic.

Brenchley (23), in her text on plant poisons, states that the toxic effect of arsenic on the higher plants (weeds) is more marked with arsenious acid and its compounds (white arsenic is an example) than with arsenic acid and its derivatives, of which arsenic pentoxide is an example. Nevertheless, arsenic pentoxide has its supporters. Woodman (119) found that a 1.5 per cent solution of arsenic pentoxide (one pound As_2O_5 dissolved in 8 gallons of water), applied at the rate of 240 gallons per acre, controlled all weeds except yarrow *(Achillea millefolium),* dandelion *(Taraxacum officinale),* dock *(Rumex sp.)* and a sorrel *(Oxalis sp.)* as effectively as the same volume of a 2½ per cent solution of sodium chlorate.

Morgan (81) also secured very satisfactory results with arsenic pentoxide in the control of hoary cress *(Lepidium draba).* In a field trial he sprayed the weeds with a 6 per cent solution of the chemical dissolved in water. Control was 93 per cent for the period of a year after treatment. His most satisfactory procedure consisted of an application of spray which contained a total of nearly 100 pounds of the pentoxide. He noted a decrease in the efficiency of the spray with an increase of rainy weather during the week before application was made. On the other hand, sunlight, high air temperatures and low humidity—factors which hastened drying out of the weeds and soil—increased the effectiveness of the treatment.

From New Zealand, Levy and Madden (70) report the pentoxide as an excellent contact herbicide for application to weeds on lawns. They comment on its ready solubility in water and state that it shows satisfactory differentiation in attacking weeds rather than grasses in lawns. They believe that when absorbed by the soil the pentoxide reverts rapidly to a non-injurious form and thereby permits early renewed growth of the established turf.

In comparing experimental trials of arsenic pentoxide and sodium chlorate, they show that chlorates tend to make the soil alkaline—an undesirable occurrence for lawns—and favor undue return of clover *(Trifolium sp.)* growth. The recovery of the lawn to a favorable green stand is less rapid following chlorate treatment as contrasted with the arsenic pentoxide applications.

In parts of Hawaii, cactus *(Opuntia megacantha)* is a common nuisance. Its eradication by spraying with chlorate solutions has met with fair success. van der Merwe (112) describes an effective method of eradicating this pest in South Africa. Young growth of prickly pear *(Opuntia megacantha)* is killed by spraying it with a solution of arsenic pentoxide, 3 pounds dissolved in one gallon of water—a solution containing about 30 per cent arsenic pentoxide. In older or more mature plants, application is made of the same concentration of the pentoxide but dissolved in concentrated sulfuric acid. Jointed cactus *(Opuntia sp.)* also yields to this treatment but only the portion above ground is destroyed.

The Fixation, Toxicity and Stimulation to Plant Growth of Arsenic Applied to the Soil:

In soils containing 20 per cent, more or less, of an iron oxide colloidal clay-like fraction, soluble compounds of arsenic are fixed at a rapid rate.

Other factors of significance regarding the soil fixation of applied arsenicals are the wide diffusion, comparatively small amounts per application and the infrequent treatments of the chemical, per crop, which are made. In short, the soil receives a very light "dressing" of the chemical a few times per crop cycle (one year to 20 months) distributed upon weed surfaces in an extremely fine state of particle division. One would expect to find, therefore, an intensive soil fixation of this applied arsenic.

Crafts (34) found the toxicity of sodium arsenite greatest in Fresno sandy loam and lowest in Yolo clay loam. The loss of toxicity with time and cropping was greatest in the Yolo soil and least in the Fresno type. Stockton and Columbia soils "held" twice as much arsenic as the Fresno soil. Amounts of arsenic "held" by all four soils was greater with increased concentrations of solutions. Even after he leached the Yolo soil with 160 surface cm. of water, the upper 4 inches of soil was "sterile." The chemical (arsenic) had not gone down below the 16-inch level. Similar leaching removed all the arsenic from the Fresno soil.

Zuccari (123) made a study in Europe of the normal occurrence of arsenic in soils. His findings have a bearing on the phenomenon of soil arsenic fixation.

In a study of 20 soil samples, varying in physical and chemical composition and taken from different depths in different geological formations and varying elevations, Zuccari found the arsenic content to vary from about 5 to 150 p.p.m. of As_2O_3 (calculated by the author).

Discussion on the Toxicity of Arsenic in Soil to Vegetative Growth, as Compiled From the Literature:

Gray (44) states that a heavy dressing of sodium arsenite upon bindweed *(Convolvulus arvensis)* on a California soil destroyed 85 to 90 per cent of the weed but did not eliminate it and further, the land remained *barren* for at least 14 months thereafter.

Morris and Swingle (82) state that apart from its poisonous properties, arsenite of soda tends to change for the worse the mechanical condition of the soil and that it is strongly "held" in the soil and is not easily washed out by heavy rains. They state that if it is used too freely the soil may be poisoned for subsequent crops. They observed that beans and cucumbers were very susceptible to arsenic in the soil, whereas cereals and grasses proved more resistant.

Safety in use of calcium arsenate for treatment of cotton as a control of boll weevil appears to depend upon the amount of iron hydroxide in the soil which supports the cotton plant. Paden (87), in studying the differential growth response of cotton and cowpea plants on certain soil types to which varying amounts of calcium arsenate were added has found that dark-colored soils and fine-textured soils may be more tolerant than either light-colored or heavy-textured soils. Cooper, Paden, et al (30), in commenting on their researches in South Carolina, state:

> It has been observed that these soil types vary markedly in their response to additions of calcium arsenate. The coarse-textured gray sandy soils . . . are seriously affected by a relatively light application of calcium arsenate, whereas the fine-textured dark-colored soils . . . are not seriously affected by applications of calcium arsenate which would be commonly used in combating the cotton boll weevil.

Many research studies on the relations of soil arsenic to plant growth reveal definite evidences of stimulation to vegetation where low concentrations of arsenic are present. Others indicate an unusually high degree of tolerance by certain plants to quite large quantities of arsenic in the soil. Still others suggest that, on the whole, arsenic additions to the soil may be beneficial rather than harmful to a large group of plants—particularly cereals and grasses (and, apparently, to sugar cane).

Results of studies supporting contrary conclusions, and, in part, those which uphold beneficial influences of arsenic upon certain crops have been cited.

John Stewart (100), for example, in an experiment, grew wheat and beans in soil and treated them, in steps, with 0 to 500 parts of soluble arsenic to one million parts of dry soil (using disodium arsenite). Stimulation in growth was observed (as compared to controls) in pots containing from 25 to 75 p.p.m. of arsenic. Checking of growth occurred in higher concentrations and death to the plants was observed in the highest concentrations. Dry weights of these plants did *not* give evidence of having been increased by arsenic in lower or stimulating concentration ranges. They did show, however, a decrease with the highest concentrations, where checking of growth or death occurred.

Granted that arsenic in low concentrations in the soil does stimulate the growth of certain higher plants, ". . . what are we to use as a criterion of such stimulation?" question Stewart and Smith (101). Quoting from their discussion:

> If stimulation occurs will the dry weight of the plant necessarily be greater than it otherwise would have been? Is not a healthy, vigorous appearance also evidence of beneficial influence? The life processes of a healthy looking plant may proceed more rapidly than those of a plant of less vigorous appearance, and the former may arrive at maturity at a somewhat earlier date than the latter without attaining a greater weight.

Pot experiments with radishes show that when grown in soils of low arsenic content they had thick, fleshy, fine-looking roots, while those grown in high arsenic soils were longer and of smaller diameter. In this case, the arsenic had a stimulat-

ing influence up to and including a concentration of 250 parts of arsenic per million of soil. A great variability to resistance or to stimulation by arsenic to various plants has been found.

Continuing quotations from Stewart and Smith:

The amount of arsenic absorbed by the plant which is necessary for the checking of growth seems to have been, in parts per million of dry plant matter, 50 for beans, 78 for potatoes, 52 for wheat, 193 for peas, and 940 for radishes. When the plant is killed the smallest amount of arsenic absorbed was shown to be 269 parts per million for wheat, 524 for potatoes, 678 for beans, 1190 for peas. . . .''

The authors question:

Is the fine, healthy appearance of plants grown in the presence of small quantities of arsenic compounds due to the destruction, by the arsenic, of soil microorganisms which are injurious to the higher plants or is it due to a direct action of the arsenic compound on the higher plant? [Water culture experiments indicate that the beneficial effect] . . . is due to a direct chemical-physical action. But both kinds of action may be involved. The problem is interesting and awaiting solution.

[Poisoning by arsenic to plants] . . . is probably due to a chemical action on the chlorophyll in which the arsenic is involved. [If it] . . . were due in the main to injury to the root or tissues of the stem, its visible effects should be seen first at the top of the plant and extreme tips of the leaves, which is exactly the opposite of what is actually observed.

[Twenty-five to seventy-five parts of arsenic per million of soil appears to be generally the range of stimulating influence.] In the case of the radish, however, this visible result [stimulation] appears in the underground part and not in the foliage.

It would, therefore, seem that the accumulation of arsenic in the soil, as a result of the spraying . . . if not continued to excess, may be beneficial rather than injurious.

It has been shown by several investigators that fungi exist which utilize compounds of arsenic in their development and multiplication. Accumulation of arsenic in the soil under conditions of water logging, i.e., reducing conditions, favor fungi utilization of the element in which it is converted to arsine, AsH_3, a gas which escapes to the atmosphere.

Reed and Sturgis (90) comment on this reduction of soil accumulation of arsenic. They also point out the marked effect of soil type upon the toxicity of the arsenic it may contain. They found that a soil extraction with 0.05 N hydrochloric acid brought into solution that fraction of its arsenic content which was related directly to the degree of toxicity to plant life shown by that soil. This method of analysis to determine soluble or toxic arsenic has been used by other workers. Reed and Sturgis state:

Arsenicals used in the dusting of cotton have had a toxic effect on succeeding crops of irrigated rice in certain soils of the Southwest.

The effect on the yield of rice of applications of varying amounts of calcium arsenate on different soil types was studied and it was found that the toxic effect was governed largely by the soil type. Rice on the lighter soils was seriously affected by applications of 50 pounds per acre of calcium arsenate, while on the heavier soils 150 pounds per acre were not injurious. No correlation could be found between water-soluble arsenic and toxicity, though a *relationship existed between 0.05 N HCl-soluble arsenic and toxicity.* (Italics ours.)

Less total arsenic was found in the soil at the conclusion of the test than was present at the beginning. An analysis of the rice heads and straw showed that the loss could not be accounted for by crop removal. The soil was found to be in a highly reducing condition when flooded under cultivation, and it is suggested that this loss in arsenic content might be accounted for by com-

plete reduction to gaseous arsine. Furthermore, the evidence seems to indicate rather conclusively that it is the reduced arsenic compounds, arsenites, etc., that are particularly toxic to rice under flooded conditions.

The relationship of the iron hydroxide and iron oxide colloids of the soil to fixation of arsenic and to the rendering of the element less toxic to plant growth by its ferrous absorption is proven very clearly by the researches of Albert (2) in South Carolina. He writes:

The results of previous years had shown that additions of ferrous sulphate to arsenic-toxic soils had benefited subsequent crop growth and that red clay soils relatively high in iron compounds had a much greater capacity to render arsenates non-toxic than did the gray, sandy soils low in iron. Since many of the iron compounds in the soil are forms of iron oxide in different degrees of hydration, the power of iron hydroxide to absorb arsenates was studied.

Iron hydroxide precipitates were prepared according to a standard method. The carefully washed precipitates were put into a relatively large amount of water, to which known amounts of sodium arsenate were added. This mixture was then well shaken and allowed to stand for some hours. It was found that the arsenic up to 0.6 per cent by weight of the ferric hydroxide was completely removed from the solution. Larger amounts of arsenic were not completely removed from solution.

Precipitates of aluminum hydroxide were prepared by a standardized method and their power to absorb arsenic from solution studied. It was found that aluminum hydroxide was not nearly as active as iron hydroxide, only small amounts of arsenic being absorbed.

These laboratory results indicate that the superior arsenic-fixing power of red clay soils, as compared to gray sandy soils, is related to the greater supply of iron-containing colloids present in such soils.

Mixtures of red clay subsoil with an arsenic-toxic gray sandy topsoil were made to learn if the arsenic would be removed. Determinations of arsenic in collodion bag diffusates gave the following results:

Topsoil	Red clay	Soluble arsenic
100%	0	0.4 p.p.m.
90%	10%	0.1 p.p.m.
80%	20%	slight trace
50%	50%	none
0	100%	none

These results indicate that a mixture of about 20 per cent red clay subsoil into a topsoil high in arsenic will preclude practically any arsenic from going into solution in the soil.

Cowpeas were planted in 2-gallon earthenware jars containing mixtures of red clay and high arsenic topsoil in order to test these results on plant growth. [The figure] . . . shows the growth made by cowpeas in a jar containing a high arsenic topsoil to which had been added 10 per cent by weight of a red clay subsoil and calcium arsenate at the rate of 100 pounds per acre. The other jar had the same treatment except for the addition of the red clay. The cowpeas in the latter jar made no growth and eventually died, whereas the plants in the jar containing the red clay produced a vigorous growth. Jars containing larger percentages of clay showed no improvement over the jars containing 10 per cent.

These results suggest the possibility of correcting arsenic toxicity by methods of tillage which will incorporate red clay subsoil into topsoil.

Greaves (45) studied the effect of arsenic upon ammonification and nitrification in soil. He found that all compounds showed stimulation in lower concentrations and toxic action in the higher. It was concluded that water-soluble arsenic may exist in such soils to the extent of 82 p.p.m. without entirely stopping ammonification and nitrification.

Additions of arsenic to soil appear to set phosphates free from the fixation soil complex and permit plant life to utilize these phosphates which otherwise may be difficultly available.

Greaves (45) concurs in this belief. He states that arsenic cannot replace phosphates in vital processes of nitrogen-fixing organisms but it can in some manner liberate the phosphoric acid from its insoluble compounds. This may be a direct or an indirect action. Arsenic stimulates the cellulose ferments and these in turn react upon the activity of the nitrogen-fixing organisms. The nitrogen-fixing powers of soil extract, of filtered soil extract and soil dried for some time are only slightly stimulated by arsenic, showing that arsenic acts mainly by the removal of a thermolabile body which occurs in the soil.

In another article Greaves (47) points out that arsenic by various means stimulates the bacterial activity of soil which results in greater crop yields. This increased growth must be looked upon as due to a stimulant and not to the direct nutritive value of the substance added. Soils so treated would wear out more quickly and produce larger crops than would soils not so treated. *It is important to know that arsenic has to be applied to a soil in enormous quantities before it retards microscopic plant life and most likely before it retards the growth of higher plants.* Other experiments have demonstrated that the addition of arsenic to a soil causes the liberation of the insoluble plant foods of the soil, especially the phosphoric acid.

In a further study of the effect of arsenic upon soil nitrification Greaves and Anderson (49) found that in a given soil Paris green was toxic at 120 p.p.m. and that sodium arsenate was toxic at 40 p.p.m. and that with the arsenate at 250 p.p.m., nitrogen fixation by bacteria was entirely stopped.

Later, Greaves (47) found that the nitrogen-fixing powers of soil were greatly increased when arsenic was applied. Soils high in organic matter fixed as much nitrogen in the presence of arsenic and in the absence of mannite (a sugar) as they did in the presence of mannite and the absence of arsenic. He found the stimulation greatest when the water-soluble content of the soil was at about 10 p.p.m. "This quantity exceeds that found in most soils so it is likely that arsenic will stimulate in place of retard bacterial activity of the soil."

Jadin and Astruc (60) make this statement: "Arsenic and manganese are of the greatest importance in the vegetable cell, the former exerting an influence comparable to phosphorus, the second favoring the oxygen reactions in the plant."

Commenting on the relationship of arsenic and phosphorus in the soil in reference to plant growth Stocklasa (103) points out that while arsenic cannot replace phosphorus in the living cell, it is able to induce the formation of furfurol derivatives and consequently increase the development of the organ of assimilation in the plant.

Picado (88) credits arsenic with having the properties of a catalytic soil fertilizer. He found, in small applications, that arsenic had a tendency to enhance the yield of corn fodder. A progressive increase in the application of arsenic indicated that it had no effect on crop yields in amounts greater than 7.32 pounds per acre. In such small quantities arsenic apparently did not act as a sterilizing agent. In sterile soil *and* in natural soil, small applications of arsenic increased the yield of

corn. The conclusion was reached that arsenic used in this manner acts as a catalyst (stimulates plant metabolism and accelerates advantageous soil reactions).

The results obtained by many research workers, therefore, indicate that arsenic in small concentrations in the soil solution on lands containing colloidal iron oxide is not harmful but actually may be of benefit. Also that to be toxic to higher plants it must be present in high concentrations in the soluble form.

Greaves (48) concludes a discussion on the subject with this statement:

The study of arsenic-decomposing fungi by Thom and Raper and their claim that the fungi will keep down the concentration of arsenic in the soil gives to the subject a brighter outlook, for if arsenic does not accumulate in soil the likelihood of injury is slight. Moreover, *the quantity of arsenic in the soil does not determine its toxicity, but rather its toxicity is determined by its solubility, which is dependent upon the chemical and biological properties of the soil.* (Italics ours.)

Toxicity of Arsenic to Animals:

Arsenic is employed largely by veterinarians as a tonic and reconditioner. Its use in this regard is common throughout the world. As in the case of plant life, small doses of arsenic appear to have at least a temporary beneficial effect on indisposed animals. Larger doses are frequently fatal to cattle or mules even though the amount imbibed may be 40 grains or less.

The discussion which follows refers principally to the poisoning of animals which may have grazed upon arsenic-treated weeds or grasses.

Husband and Duguid (58) found that cattle which received more than 30 grains of white arsenic in one dose, by mouth, eventually died from the effect. When given 20 grains they all survived. Thirty grains caused death in 86 hours, 56 grains in 73 hours and 112 grains in 40 hours. When confined to areas which had been sprayed with 1½ pounds of sodium arsenite per acre, cattle ate sufficient of the grass to be poisoned.

Cattle, other animals, and men develop a degree of immunity to the toxic effects of arsenic when this substance is administered regularly, first in small doses and thereafter in progressively larger ones. Besredka (16) induced immunity to the toxic effects of arsenic upon the skin of rabbits by repeated applications of the chemical in an ointment to a preselected area on a partially shaved animal. Immunity was confined to the treated area of the skin, but no anti-body was produced by the animal.

Woodman and Wiley (121) have found that the addition of certain coal tar derivatives as an emulsion to an arsenical spray solution increases the toxic effect upon treated weeds and imparts such an unpleasant taste to them that animals will not eat them. Cresols may be selected as the coal tar preparation and glue may be employed to emulsify the mixture.

As an illustration of the harmless effects of arsenic when taken by animals in small quantities over an extended period of time, Frederick (40) reports that alfalfa hay, when dusted with 3 to 6 pounds of calcium arsenate per acre and fed to cattle, horses, and sheep for 40 days, with no other food except water and salt, showed no noticeable injurious effects to this livestock.

When dusted with 2 pounds of calcium arsenate per acre (common practice for controlling alfalfa weevil), alfalfa, so treated, may be fed freely to livestock for a

whole feeding season without harming them. He added that where arsenic-treated alfalfa hay was fed the animals, more water was consumed by them, but not as much hay. Apparently the arsenic in the treated hay, he states, acted as a stimulant or tonic for the animals. (This statement does not appear to be logical. The author's understanding of the effect of a stimulant or tonic is to *increase* consumption and utilization of food to the general betterment of the animal.)

When rabbits succumbed after receiving repeated poisonous potions of arsenic, Schonberg (94) found that the ingested arsenic appeared in the liver, kidneys, brain, skin, and fur of the dead animals.

Johnson (63) recommends that arsenic trichloride be employed for weed destruction because its taste is repulsive to animals and they avoid it. He states that the arsenite compounds ordinarily used upon sprayed vegetation are attractive to grazing animals and is so toxic that a few mouthfuls may cause death.

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The Prebaited Feeding-Station Method of Rat Control

By R. E. Doty

Introduction

Every control method or plan for poisoning field rats that has shown a reasonable efficacy when first tried has dropped in effectiveness with time. While this may be partially due to a gradually developed indifference on our part with a cessation of the active control measures, the factor of prime importance is the uncanny ability of the group of surviving rats to circumvent the plan and quickly repopulate the area.

In the past, rat control in Hawaii has been based chiefly on the use of poisoned grain wrapped as torpedoes; more recently the Bureau of Biological Survey, United States Department of Agriculture, has used meat pellets or sausages. These methods were highly developed through extensive and painstaking trials by many workers, yet in some cases serious difficulties still remain which prevent satisfactory control.

Heavy losses from molds occur when torpedoes are distributed in fields receiving a heavy rainfall. It is very difficult to make a waterproof package without reducing its attractiveness to rats. All good baits spoil easily when exposed in the open fields. Ants and cockroaches eat holes in the covering of the torpedoes, thus allowing moisture to enter and spoil the bait very quickly. On any large-scale operation it is impossible to determine how many torpedoes are being eaten. Hence a liberal number of torpedoes are generally distributed in order to insure enough for the entire population. The result is that large numbers remain in the field to spoil in a few days, and it is common experience to find plenty of moldy torpedoes along the routes of earlier distributions. Moreover, some of the large-sized torpedoes that were formerly used contained such low concentrations of poison that they could not be effective unless eaten in quantity. These conditions have been noted at the Kauai Variety station and elsewhere. The most serious problem of all in the use of poisoned bait is the fact that only a small proportion of the torpedoes are entirely eaten, while many more are partially eaten or only nibbled.

From many personal observations, it is our belief that, with ample natural food present in a cane field, many rats are suspicious of any newly discovered food supply and only nibble at or entirely refuse to eat it for 2 or 3 days; even though it is of the best non-poisonous material. Thus it is not so much a case of their detecting the poison in the poisoned bait as it is their general suspicion of any new food supply. If this is the actual situation, poisoned bait placed directly in the field very frequently is merely sampled. Large numbers of rats, then, do not get a lethal dose the first time they nibble a torpedo, and the resulting discomfort renders them definitely bait-shy. Perhaps they warn others of the danger also. These defects have recently been partially overcome by increasing the concentration of the poison, so that a much smaller portion of bait would carry a lethal dose. Garlough and Spencer (6), of the Biological Survey, have increased the poison ratio to as high as 1 part in 64.

The present paper presents and discusses a different plan of attack which promises to be a valuable aid in practical field-rat control. Details of all experiments herein discussed are recorded under Project A-108 in the files of the Experiment Station.

Plan

The plan consists in feeding field rats unpoisoned grain which has been placed in containers under a cover and exposed for several days (6 days or more), until a large part of the surrounding rat population has discovered the new source of food and has formed the habit of visiting these specific feeding places. If it is true that "in every tribe there is an official taster"* who samples the new food first, then the six days during which unpoisoned grain is exposed would be sufficient to insure success for the plan. After the rats have acquired the habit of visiting these stations regularly and have gained confidence in the food, the operator removes the unpoisoned grain from these feeding stations and substitutes poisoned grain in its place. Owing to the familiar surroundings and the apparently identical food, the rats will return the following night to eat a lethal dose without suspecting the deception. It is advisable to make the substitution over a large area on the same day so that there will be the fewest possible unpoisoned rats able to observe the plight of their companions and perhaps become educated to the deception. Even the best-educated rat cannot predict when the change from unpoisoned to poisoned bait will be made on a subsequent campaign as this depends on such circumstances as weather and the whims of the operator. This plan should be effective, even following recent direct poisoning with torpedoes, irrespective of the bait used, but rolled oats stand out as the most efficient bait at present. Owing to the large quantity of oats being consumed at the time poison is administered, high concentrations of the poison are not necessary because the rats are eating freely, instead of nibbling to sample the food as formerly.

The method of prebaiting using covered feeding stations has advantages over direct poisoning with torpedoes. At the beginning of the field experiments in prebaiting, it was believed that the additional labor necessitated by the extra visits to the field would make the method unduly expensive, but after a demonstration, it was found to be practically balanced by the elimination of the expense of wrapping each individual torpedo by hand.

There should be less waste from spoilage of grain under this plan. If reasonable care is taken to keep the grain dry as it is placed in the pans under the iron covers, it should keep at least 4 days even during very wet weather. This is long enough for the rats to find the stations and any station that has not been visited in that time should not be baited with the expensive poisoned grain. Intelligent placing of the poisoned oats, based on knowledge of previous unpoisoned oats consumption, should cut the spoilage of the expensive poisoned oats to a minimum. Most of the poisoned grain eaten at the active stations is consumed on the first and second nights, while it is still fresh, with little or no acceptance after that time. Only the surplus grain would be left to spoil. Unpoisoned oats cost approximately 4½ cents per pound while the value of the poisoned oats is from 13 to 17 cents per pound.

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* Henry Morton Robinson, "Pied Pipers, Inc.," Review of Reviews. March 1937.

By keeping some records of consumption, this plan also offers a practical means of determining the relative density of the rat population in a specific area without resorting to expensive trapping trials. In all tests with prebaiting, it was noted that there was no (or very little) consumption of grain for the first few days, but in less than a week a large clientele had been built up. The progressive increase in consumption remains the most vital factor in the success of the plan; without this increase there would be little or no advantage over direct poisoning.

The idea of prebaiting animals is not new. The Biological Survey has used prebaiting for coyotes on the mainland. Referring to rats, Silver (9, p. 7) states that "In stubborn cases, or when one is willing to go to additional trouble to increase the chances of success, prebaiting is recommended. This consists of exposing fresh, unpoisoned baits, prepared precisely as the poisoned baits will be later on except for omitting the poison. If these are taken freely the first night, poisoned baits should be substituted after an interval of one or two nights. Otherwise clean baits should be exposed at two or three day intervals (picked up in each case the following morning), until any suspicion the rats may have has been overcome and they take the baits without hesitation. When this occurs, they will doubtless take the poisoned bait the next night, and then the result should be a complete clean-up of the infestation."

Prebaiting of rats on a field scale in Hawaii is the result of experimentation since April 1935, following C. E. Pemberton's suggestion that some form of prebaiting should be studied along with our torpedo work. The idea of trying to make this plan of practical use began at the Manoa substation when various grains were placed in open tins under box covers to allow the rats to express their preference in grains.* The rats returned each night in such increasing numbers that liberal quantities of the popular foods were required to keep the tins filled. After trying other tests using unpoisoned grains with various oil attrahents, poison was applied to these feeding places with very effective results. Other tests of food preference and poisoning were continued at intervals until March 1936. Poisoning of rats by feeding under shelters was discontinued at the Manoa substation in April 1936, following the unfortunate poisoning of three dogs that ate the rolled oat briquettes (Experiment No. 25), and after some delay a small area at the Kailua substation was used in testing types of wood and metal containers (Experiment No. 27). The square tin pans with galvanized iron covers proved the most practical and a supply was made up for further study. Another test was conducted at Kailua in August 1936 (Experiment No. 28), followed by one at Waipio in January 1937 (Experiment No. 31). At this same time, in response to a request by George Y. Bennett, manager of the Waimanalo Sugar Company, a larger test (Experiment No. 30), was carried out on that plantation.

R. L. Walker, agriculturist at Kaeleku Sugar Company, who had collaborated in the Manoa experiments, fabricated some boxwood shelters and placed them in the field. Loose unpoisoned barley was put in these shelters for from 4 to 8 days followed by poisoned barley. Mr. Walker's report to Manager J. F. Ramsay, of Kaeleku Sugar Company, dated May 19, 1936, states "These tests show that this

* The favorite was (1) sunflower seed, followed in order by (2) rolled oats, (3) rolled barley, (4) cornmeal, (5) cracked corn, (6) wholewheat, and (7) milo maize.

method can be used successfully to feed poisoned bait to rats with comparatively little waste. The only noteworthy objection to this method that occurs to the writer is the awkwardness which the transportation of any considerable number of these hoppers would involve if they were placed in locations at a distance from an auto road."

During April and May, 1937, two field tests were conducted, one at Kilauea Sugar Plantation Company and the other at Grove Farm Company. With the cooperation of the managements these tests were operated on a sufficiently large scale (90 and 143 acres respectively) to make the results significant. Three other minor experiments were conducted at Kilauea Sugar Plantation Company at the same time. In July 1937, an experiment to demonstrate the value of sweetening the poison formula was conducted at the Pepeekeo Sugar Company and at the Hilo Variety station.

Each successive test gave additional or confirmatory information and various changes and refinements were introduced as the work progressed. The findings to date show that this plan of poisoning rats may be applied to most field conditions with satisfactory results.

Equipment

A simple and inexpensive feeding station as developed at present consists of a small, tinned baking pan 7 by 7 by 1¼ inches placed under a curved cover, shaped like the tops of the old covered wagons, made of a 15- by 16-inch piece of light (28-gauge) galvanized iron. To curve the covers into a half cylinder they may be shaped over a piece of 6- or 7-inch pipe or by a tinsmith's roll-forming machine. The square, almost vertical-sided baking pans are preferable to the round sloping-sided pie pans, as their use practically eliminates the spilling and consequent wasting of the grain. For convenience in keeping records of the stations, each cover should be numbered before bending, using a good waterproof paint. Ordinary lettering lampblack will smear, especially after the covers have been freshly treated with raw linseed oil. With exposure to the weather, the covers lose their shine and soon blend into the landscape. It may be advisable to paint a yellow or white stripe along the top to increase their visibility.

Both the pans and covers nest together in compact form, making for convenience in distribution through the fields. One man can carry at one time the complete equipment for 20 stations (see Figs. 1 and 2). This consists of 20 pans weighing 6 pounds, 20 covers weighing 26 pounds, and at least 5 pounds of grain in a burlap or preferably a waterproofed canvas bag slung over the shoulder. The covers may be carried under the arm or on the shoulder while the pans may be carried in the other hand or in the bag with the grain. It is recommended that raw linseed oil as an attrahent be rubbed on the inside of the covers before they are taken to the field. The approximate cost per station based on Honolulu prices is about 18 cents; 11 cents for the cover, including cutting, and 7 cents for the pan. A sheet of 28-gauge iron, 30 by 96 inches costing about $1.07 will cut into twelve 15- by 16-inch pieces.

It has been recommended that stations be placed four to the acre. Allowing an interval of three months between poisoning campaigns in any given area with the stations in place 10 days, 45 stations costing about $8.00 for permanent equipment will serve 100 acres. For a 2-month interval 70 stations are necessary.

Fig. 1. Materials for twenty feeding stations ready for distribution in the field. Twenty covers carried under the arm (weight twenty-six pounds); twenty pans carried in the other hand or in the bag (weight six pounds); and five pounds of grain carried in the bag.

Fig. 2. Same materials as shown in Fig. 1 showing covers placed on the shoulder as an alternate carrying position.

Fig. 3. Filling the pan with rolled oats. One cupfull (one-quarter pound) is a convenient amount of unpoisoned grain.

Fig. 4. Inserting the pan under the cover.

Bait

The experimental work with prebaited feeding stations has been done with a good quality of bulk *rolled* (not crushed) oats. A good grade of rolled barley would serve as a substitute but is wasteful because the hulls, which the rats invariably leave, will retain an appreciable amount of poison. Rolled grains have distinct advantages over whole kernels, in being more attractive to the rats and a better absorbent of the poison solution.

Under extremely wet conditions, rolled oats, placed in stations surrounded by dense weed growth where there is poor circulation of air, will mold from condensation of moisture in 3 to 4 days. Some loss will occur from this cause in the less active stations, during periods of high humidity and frequent rains. Spencer (7), of the Biological Survey, has reported some benefit from the use of sodium sulphite in rat bait as a protection against spoilage. Grove Farm Company is now testing rolled oats containing one per cent sodium sulphite as a mold deterrent in field trials. A preliminary test conducted several years ago with sodium benzoate proved unsuccessful.

Many poisons have been used in rat control, and of these the most efficient to date has been thallium sulphate which was used exclusively in these tests in concentrations varying from 1 to 250 to as high as 1 to 100. The poisoned oats used in the Kilauea Sugar Plantation Company and Grove Farm Company experiments, as well as two small early experiments at the Kailua substation, all carried thallium sulphate at the rate of 1 pound to 250 pounds of oats. At Waipio substation and at the Waimanalo Sugar Company the poison used was much stronger (1-100). While a smaller quantity of poisoned oats is needed for a lethal dose in the 1-100 formula, the abrupt drop in consumption often noted on the first night of poison may indicate some detection of the change. In a small test at the old Manoa substation (Experiment No. 25), the rats showed little preference between poisoned and unpoisoned briquettes on the first night of the poison exposure, but after the third night the surviving rats showed a decided preference for the unpoisoned grain; the consumption of unpoisoned oats increased while the poisoned oats remained practically untouched. From this it appears that rats are readily educated to detect poisoned material even though thallium is recognized as being both odorless and tasteless. In a test at the Waimanalo Sugar Company (Experiment No. 24) comparing poisoned and unpoisoned rolled barley and rolled oats in adjacent pans, the rats ate 10 per cent less barley and 27 per cent less rolled oats from the poisoned pans than they did from the unpoisoned pans.

The minimum lethal dose (M.L.D.) of thallium sulphate has been studied by several investigators. Munch (8, p. 20) reported that "the minimum lethal dose . . . was found to be . . . 31 milligrams of thallium sulphate per kilo, [of body weight] when fed to rats." Recent studies by Garlough and Spencer (6) indicated 30 milligrams to be lethal. This disregards any possible neutralizing action of food acids.

To better visualize what this means in practical terms, the following tabulation of theoretical killing power of the various concentrations of poisoned rolled oats has been prepared.

TABLE I

THEORETICAL EFFICIENCY OF THALLIUM SULPHATE EXPRESSED IN WEIGHT OF RATS KILLED

Concentration of thallium sulphate		1–64	1–100	1–150	1–200	1–250	1–666*
Milligrams of thallium sulphate per pound of oats		7087	4536	3024	2268	1814	681
Weight of rat that should be killed per pound of oats	(kilos)	236	151	101	76	61	23
	(pounds)	520	333	222	166	133	50

* This was the accepted concentration formerly used in torpedoes.

These weights are calculated on the basis of 30 milligrams of thallium sulphate as a lethal dose for 1000 grams of body weight of rats.

Example: Taking the 1-100 concentration we have:

$$1 \text{ lb. oats contains } \frac{4536 \text{ mg. thallium}}{30 \text{ mg. (M.L.D.)}} = 151.2 \text{ kgs. or } 332.6 \text{ lbs. of rats.}$$

This is equivalent to approximately 450 adult *Rattus norvegicus* (Erxlelen) or 2,000 *Rattus hawaiiensis* (Stone). (The average weight of an adult *norvegicus* is approximately 325 grams, and of the little *hawaiiensis* 60 grams.)

TABLE II

WEIGHT OF RAT KILLED BY 1, 2 AND 3 GRAMS OF POISONED OATS AT THE VARIOUS CONCENTRATIONS

Concentration of thallium sulphate	1–64	1–100	1–150	1–200	1–250	1–666*
1 gm. oats should kill.....(pounds)	1.1	.7	.5	.4	.3	.1
2 gms. oats should kill.....(pounds)	2.3	1.5	1.0	.7	.6	.2
3 gms. oats should kill.....(pounds)	3.4	2.2	1.5	1.1	.9	.3

* This was the accepted concentration formerly used in torpedoes.

The last column of Table II shows that three grams of grain of the old 1-666 formula would kill only a small half-grown rat weighing .3 pound. Some old formulas were even weaker (1-1000) and proportionately more bait was required to kill. Under normal field conditions there are other foods available and there is little doubt but that many rats were satisfied before a lethal dose had been eaten. Thallium salts applied externally are strongly depilatory and sub-lethal doses of these salts taken internally have the same property of causing the hair to fall out. Hairless or partially hairless rats were reported during this period of low bait concentration. These individuals which had taken the poison in quantities insufficient to kill were in all probability bait-shy thereafter.

Again referring to Table II, we note that 2½ grams of oats of 1-250 concentration will kill a large rat weighing three-quarters of a pound, which is about the average for an adult Norway rat, *Rattus norvegicus* (Erxlelen), the common field rat on Kauai. If the concentration is increased to 1-200 only 2 grams of oats are required to kill a rat of the same size. If the concentration of thallium is further increased to 1-100 only one gram is required. For all practical purposes a concentration of 1-200 should be sufficient for the prebaited feeding-station method when the rats have developed the habit of eating freely, as under these conditions the rats eat much more than the minimum lethal dose. It is recommended that the concentration of poison in rolled oats be not less than 1-250. If barley is used, this mini-

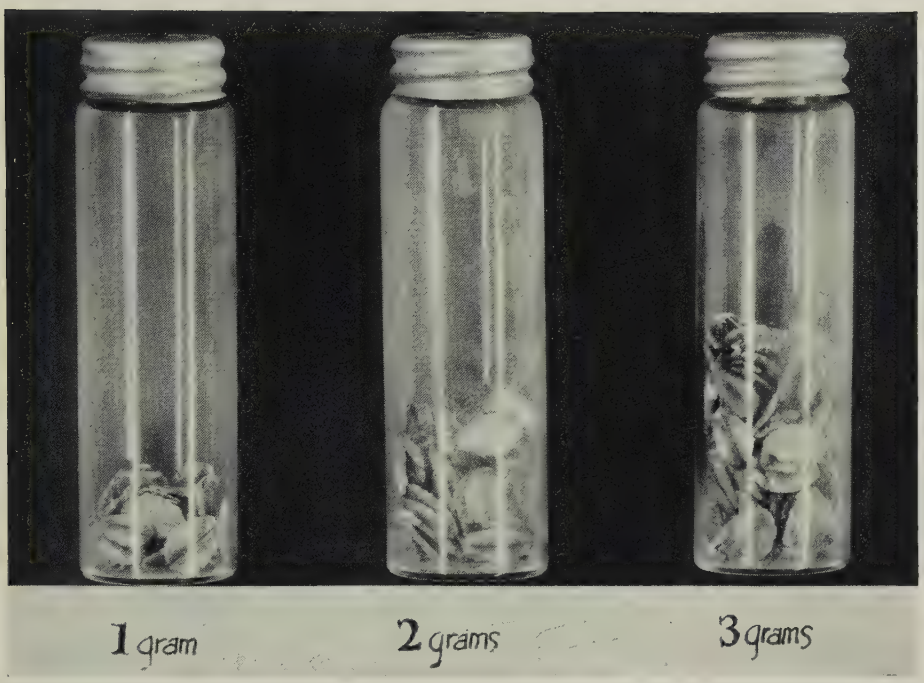


Fig. 5. An idea of the amount of rolled oats represented by one, two, and three grams (actual size). The weight of rat killed by these amounts of poisoned oats is shown in Table II.

mum concentration should be not less than 1-200, due to the loss of poison on the hulls.

While it cannot be stated exactly what the average consumption of oats by a large rat may be under field conditions where natural food abounds, it is probably between 3 and 5 grams at a time. Thus, taking 3 grams of 1-200 poisoned oats as an average consumption in the field, one pound of this material should account for 151 rats. If the average consumption should reach 4 grams each, one pound of poisoned oats will still be sufficient to kill 113 full-sized rats. On the above assumption, increasing the concentration of thallium merely gives an overdose—a margin of safety or insurance—and does not necessarily increase the number of rats killed per pound of poisoned bait. In dealing with high concentrations such as 1-64 or 1-100 we have, in addition to the greater cost of the poison, the increased possibility of the rats detecting the poison in some way, as was suggested by Manoa Experiment No. 25.

Attrahents for Grain Baits:

Many experiments on the subject of attrahents for grain baits have been conducted. Experiments performed locally in 1932 showed corn oil (1) to be superior as an attrahent to coconut or sunflower oil, and any one of these oils when mixed with paraffin was superior to pure paraffin which had previously been used for waterproofing torpedoes. Later studies indicate, however, that paraffin in any amount is

objectionable to rats. In 1935 several small tests (2) were conducted with Japanese cooking oils (Goma abura and Ageabura) at the Manoa substation, and they were found to be useful as possible substitutes for corn oil.

K. R. Gard (5), of the Colonial Sugar Refining Company, Ltd., Sydney, Australia, reported that raw linseed oil made their wheat baits very attractive and was then "being used in all baiting, both with traps and poisons." Experiments (3) on Oahu also showed raw linseed oil to be very attractive to rats and compared favorably with and sometimes exceeded corn oil or coconut oil. When any paraffin was used with either corn oil or coconut oil it so reduced their attractiveness that raw linseed oil was distinctly superior. Eckart (4) reported that "rats prefer raw linseed oil to corn oil" but he did not mention that paraffin had been mixed with the corn oil. Corn oil is more expensive ($2.25 per gallon) than raw linseed oil ($1.15 per gallon) or coconut oil ($1.00 per gallon). Joseph Caceres, Health Officer, Island of Hawaii, has used bacon oil as an attrahent for torpedoes with excellent results.

From the results of experiments by many workers, it is agreed that some oil attrahent may be used with benefit in all rat baits. In the prebaited feeding-station method, however, the kind of oil appears of less importance than with the torpedo method, so long as some attrahent is used to help the rats find the station quickly. The best attrahents found thus far are corn oil, raw linseed oil and coconut oil, in that order.

The oil is not mixed with the bait in any definite proportion but only in quantities sufficient to flavor it and to attract the rats by its smell. In practical tests one quart of oil has been found sufficient for 10-15 pounds of rolled oats.

Rubbing raw linseed oil on the under side of the cover of each station when it is first put out in the field is undoubtedly an aid to the rats in finding the station and this should reduce the amount of oil necessary in the grain itself. Applying raw linseed oil to the hands, with or without gloves, may be beneficial in masking the human scent that is left on the pans and covers during normal handling. The value of this procedure has not been proved, but it may contribute to the general success of control measures.

Benefit from Sweetening the Poisoned Bait:

A recent test (Experiment No. 32) conducted at Pepeekeo Sugar Company and at the Hilo Variety station compared sweetened with unsweetened rolled oats, first unpoisoned and later poisoned. Regular feeding stations were placed in the field in pairs, one station of each pair contained sweetened and the other unsweetened rolled oats. All stations were changed to poisoned oats (1-200) in the usual way after 6-7 days exposure of unpoisoned grain.

The results, summarized from 70 pairs of stations, are given in Tables III, IV and V. The number of comparisons given in Table V (Summary of Differences) is less than the total number of pairs (70) because no differences were possible when both stations of a pair were entirely cleaned out.

The average daily consumption in grams is presented graphically in Fig. 6.

Graphic Presentation Of The Average Daily Consumption In Grams Per Active Station Of (1) Sweetened And (2) Unsweetened, Rolled Oats For The Three Priods Of The Test (From Table V)

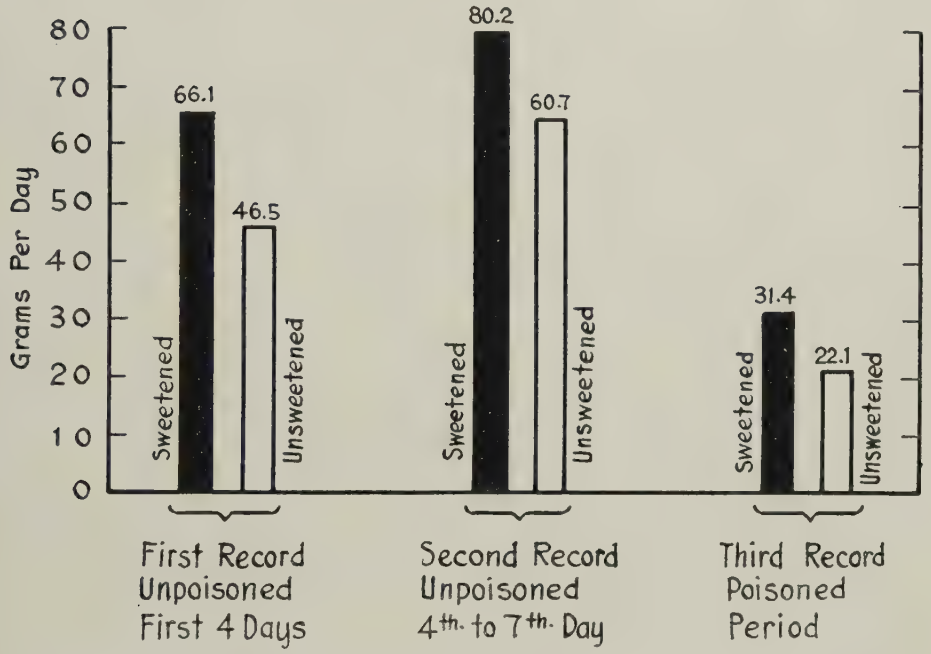


Fig. 6.

TABLE III

SUMMARY OF PREBAITED FEEDING STATIONS COMPARING SWEETENED AND UNSWEETENED ROLLED OATS

Pepeekeo Sugar Company and Hilo Variety Stations

Interval days after placing oats	4 Unpoisoned		3 Unpoisoned		3 Poisoned	
	Sweetened	Unsweetened	Sweetened	Unsweetened	Sweetened	Unsweetened
No. of stations showing no acceptance	12	12	2	5	11	15
No. of stations showing some acceptance	56	56	68	65	59	55
Total grams eaten	4570	3555	6440	5282	2012	1422
Total eaten expressed in pounds	10.06	7.83	14.18	11.63	4.43	3.13
Total difference or *loss* in lbs. when sugar was left out		—2.23		—2.55		—1.30
Total difference or *loss* expressed in per cent		—22.2		—21.9		—29.3

TABLE IV

STATION-TO-STATION COMPARISON OF CONSUMPTION OF OATS

Treatment	Total pairs visited by rats	Favoring sweetened	Favoring unsweetened	Even
Sweetened vs. unsweetened first 4 days; unpoisoned	60	33	17	10
Sweetened vs. unsweetened next 3 days; unpoisoned	69	43	11	15
Sweetened vs. unsweetened; poisoned period	64	40	18	6
Totals of all records	193	116	46	31

TABLE V

SUMMARY OF DIFFERENCES (STUDENT'S METHOD)

No. of comparisons	Treatment	Avg. daily consumption per active station (in gms.)	Loss for unsweetened gms.	Loss for unsweetened %	Signif.
	(First record, first 4 days, unpoisoned)				
52	Sweetened oats	66.1			
52	Unsweetened oats	46.5	—19.5	—29.5	Very high
	(Second record, next 3 days, unpoisoned)				
59	Sweetened oats	80.2			
59	Unsweetened oats	60.7	—19.6	—24.5	Very high
	(Third record, poisoned oats)				
64	Sweetened oats	31.4			
64	Unsweetened oats	22.1	—9.3	—29.6	Very high

Discussion of Results: A direct comparison of the total consumption of sweetened vs. unsweetened oats shows a consistent loss for the unsweetened oats of 22 per cent for the first 4 days, not poisoned; 22 per cent loss for the second unpoisoned period (3 days), and 29 per cent loss for the poisoned period. (See Table III.)

A station-to-station comparison of consumption for the 3 periods of feeding shows that out of a total of 193 paired records, 116 favored the sweetened oats, 46 favored the unsweetened and 31 were exactly even. (See Table IV.)

A statistical study of the summary of differences from the paired stations by Student's method shows a consistent loss for the unsweetened oats ranging from 25 to 30 per cent below the standard sweetened formula (See Table V), and indicates that the present sweetened poisoned formula* should be continued without change. The odds based on these differences denote a very high significance.

These results indicate also that some benefit will accrue from sweetening all of the prebait used in the feeding stations. While the perfect prebait should be prepared exactly like the final poisoned bait except for the poison, we have not advocated this as plantation practice until we are sure that the additional expense of this extra

* Rolled oats: 900 pounds.
Brown sugar: 28¾ pounds.
Corn syrup: 9 pounds.
Water: 8 gallons.
Thallium sulphate—variable according to orders of customer, ranging from 1-100 to 1-250.
(Courtesy of the Pacific Guano and Fertilizer Company.)

processing is justified, since this additional treatment would probably increase the cost of the unpoisoned bait 2 or 3 cents per pound.

Procedure in the Field

Distributing the Stations:

The necessary quantity of the equipment previously described together with a supply of unpoisoned oats should be taken to the field and distributed at convenient points along the road. The distributor takes a load of approximately 20 complete stations and proceeds to set up stations in selected places. In previous work the stations were usually spaced from 90 to 100 feet apart along the level ditches, trails, roads, or edges of the field, placing about 4 stations per acre. The stations were spaced roughly equidistant, but the exact spot for a station was determined by the ease and speed of setting it upon fairly level ground. The stations should not be placed in a depression or ditch as heavy rains flood such areas and fill the grain pans. The stations should be placed where good cover is offered along the edges of, or slightly within, the cane or brush. No attempt should be made to hide the stations in the cane, although they should be off the trail sufficiently to avoid tripping over them during subsequent visits.

The stations may be spaced much closer (45-50 feet apart) where the fields border on a gulch or other wasteland with heavy growths of grass, brush, or other good shelter (i.e., Panicum grass, honohono, lantana, guava). It has been noted in the large field tests conducted at Grove Farm Company, and Kilauea Sugar Plantation Company that there are many definite, well-worn trails running directly from the gulch cover into the cane. The stations should be placed closer under these conditions to try to intercept and divert this direct rat traffic. A closely spaced line of stations along the edge of a rat-infested gulch, adjacent to very young cane is an ideal arrangement, and will greatly reduce or may entirely eliminate the necessity of placing stations inside the field at a later date, after the cane has closed in. This procedure should greatly reduce the average number per acre for the whole field. Our present data indicate that lines of stations within the field should not be more than 250 feet apart. The greater the distance between stations, the longer must be the period of exposure of unpoisoned oats before changing to poisoned in order to insure adequate control. Some record of the route and the location of the stations should be kept by the operator so that he can revisit them easily after the proper interval.

Filling the Stations (See Figs. 3 and 4):

During the first trip the stations are placed and a measured amount of unpoisoned oats poured into each pan. A convenient amount was found to be ¼ pound, which exactly filled a kitchen measuring cup or a one-pound flat pineapple tin. In our experimental work, an accurate study of the consumption of oats was made and recorded for each station. This was done by measuring and estimating on the basis of one cupful (¼ pound) being divided into 100 parts and the consumption read in per cent. Commercially this is not necessary, but some sort of record should be made, especially during the last two days of unpoisoned prebaiting in order to be able to gauge intelligently how much of the expensive poisoned oats should be placed

RODENT CONTROL RECORD - Field No. _____

Dates Sta. Nos.	Location Notes	Not Poisoned: Refilled 1st. Record	Not Poisoned: Poison placed 2nd. Record	Poisoned: Pick-up Stations Poison Record

Recorded by: _____

Fig. 7.

in each station to supply the demand without waste. A suggested plan for recording the observations has been prepared and is available in mimeograph form. (See Fig. 7.)

There is so little acceptance during the first two days of prebaiting that no useful purpose is served by inspecting the stations so soon, but after four days an inspection should be made to renew the oats as the rats will have begun to feed more confidently. If the grain is dirty, moldy or otherwise unattractive it should be discarded. Sufficient grain should be placed in the pans during this visit to assure a supply for the two or possibly three nights of prebaiting remaining before poisoning, otherwise the efficiency may be reduced. Consumption during this last period of 2 days of unpoisoned grain will exceed the total eaten during the first four days. The third visit should follow in two or three days, at which time any remaining unpoisoned oats should be removed and poisoned oats substituted.

The poisoned grain should remain in the pans at least three days before the stations are removed during the fourth and final visit. As shown elsewhere in the experimental evidence (see page —), less than one per cent of the total poison eaten was normally eaten after the third night. The stations may be left four days or more to catch this final one per cent if it is not urgent to remove them sooner.

Time Interval Between Visits:

Briefly then, the pans are placed in the field, filled with unpoisoned grain and covered, on the first trip through the field. On the second trip four days later the unpoisoned oats are renewed. The third visit should be made two or three days

after the second trip at which time any unpoisoned oats are removed and poisoned oats are substituted. Following three or four days of exposure with poisoned oats, the stations may be picked up on the fourth visit and moved to a new area. This procedure requires a minimum of 9 days for one poisoning cycle. Under special conditions it may be advisable to prolong the period of prebaiting with unpoisoned oats, but this will increase the consumption very materially. J. W. Anderson reports that he has had to wait as long as 9 days to build up a satisfactory acceptance of unpoisoned oats at the Kauai Variety station.

Interval Between Poisoning Campaigns:

Rats appear to migrate from distant wastelands to reinfest treated cane areas in a comparatively short time. Until we have more information it would seem advisable to repeat control operations in about 3 months. Special attention should be given to the edges of young cane adjacent to waste areas or near recently harvested fields.

Gulch areas adjoining harvested fields should be treated very soon after harvest while the localized food supply is low. When in doubt as to the necessity of repeating the poisoning process, test stations may be placed at strategic points for observation.

Personnel

The success of this method of rat control is entirely dependent on the men in the field. They must be intelligent and absolutely reliable and able to work largely by themselves on their own initiative. They should have a genuine interest and pride in doing their work precisely and well. Some sort of a premium or bonus system of pay for rat control work would serve to emphasize their responsibility and reward their efficiency. As these men walk their routes through the fields they should seek to increase their efficiency in the placement of the stations by careful observations of the conditions of natural rat cover which lie immediately adjacent to the cane. The exercise of judgment in placing the required amount of poison in the various stations, based on a knowledge of previous consumption of unpoisoned grain, will prevent waste, especially during rainy weather. A brief field report showing the approximate consumption of bait by stations will help to keep up the interest and efficiency of the men as well as to afford a check on their effectiveness. The field form suggested in Fig. 7 may be useful for this purpose.

Precautions for Field Operator

After many days of observation while operating the feeding stations in the field, one is too well aware of the filthy mess that the rats can make around active stations during wet weather. In certain extremely wet areas, infectious jaundice (Weil's disease, Spirochetal jaundice) may be present among the rats. It is possible for the operator to catch the disease by contact of rat urine with a cut or scratch on the hand. To guard against this possible infection, the hands and arms should be washed in creolin solution before and after the work, and rubber gloves should be worn while handling the stations. If care is exercised to always handle the pans with one particular hand, perhaps a glove on that hand might be sufficient. It is also advisable to wear waterproof shoes or boots to prevent the possibility of infection by water through faulty footwear as has been reported in Australia.

Experimental Evidence

The experiments which were conducted in the development of this plan are briefly discussed in the following pages.

KAILUA SUBSTATION

Two preliminary tests were conducted at Kailua to determine the value and practicability of feeding loose unpoisoned bait followed by poisoned bait in open feeding hoppers.

The first test (Experiment No. 27) consisted of only 13 stations placed along the stream bed at the Kailua substation. The results from these stations were so promising that further work was planned. The second test (Experiment No. 28) was started about one month later. The area included some of the same land along the stream and brushland that had been in the former skirmish test. Twenty-five stations were spaced 90-100 feet apart in a continuous line along the edge of the field. These were visited daily except Sunday for 19 days.

The results are tabulated in Table VI.

TABLE VI

SUMMARY OF PREBAITED FEEDING STATIONS—KAILUA SUBSTATION, EXPERIMENT NO. 28

Oats put out in 9 stations September 28, and in 16 more stations September 30, 1936

Dates	Total stations placed	No. stations showing acceptance	Total oats eaten per day (grams)	Avg. daily acceptance per active station (grams)	Total eaten per day (pounds)
		UNPOISONED			
Sept. 29, 1936	9	0	0	0	0
Sept. 30, 1936	9	2	113	56	.25
Oct. 1, 1936	25	7	196	27.5	.43
" 2	25	13	613	47	1.35
" 3	25	19	783	41	1.73
" 4*	25	21	672	32	1.48
" 5*	25	21	673	32	1.48
" 6	25	18	698	39	1.54
" 7	25	20	936	47	2.06
" 8	25	22	1146	52	2.53
" 9	25	20	1288	64	2.84
" 10	25	17	1328	78	2.93
" 11*	25	25	1254	50	2.76
" 12*	25	25	1254	50	2.76
" 13	25	24	1771	74	3.90
		POISONED			
" 14	25	18	783	43.5	1.73
" 15	25	0	0	0	0
" 16	25	0	0	0	0
" 17	25	0	0	0	0
" 18	25	0	0	0	0
" 19	25	0	0	0	0

*=average of Sunday and Monday.

The total oats eaten per day has been plotted on the graph in Fig. 8.

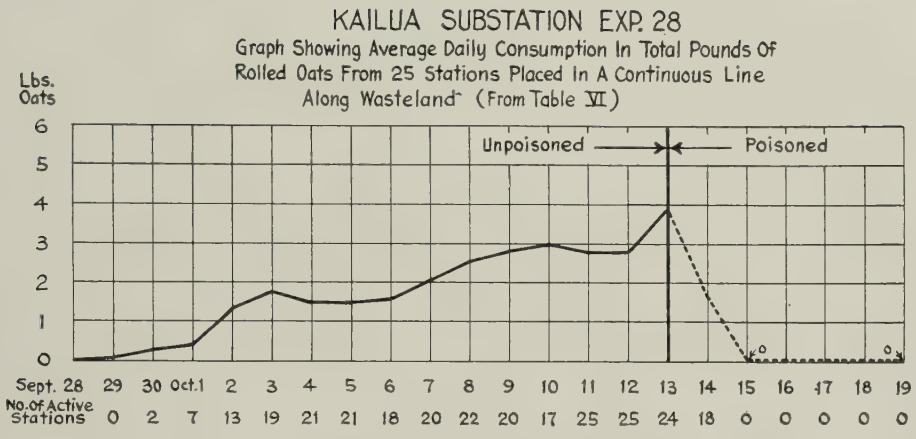

KAILUA SUBSTATION EXP. 28
Graph Showing Average Daily Consumption In Total Pounds Of
Rolled Oats From 25 Stations Placed In A Continuous Line
Along Wasteland (From Table VI)
Lbs. Oats
Unpoisoned
Poisoned
6
5
4
3
2
1
0
Sept. 28 29 30 Oct.1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
No. of Active Stations 0 2 7 13 19 21 21 18 20 22 20 17 25 25 24 18 0 0 0 0 0

Fig. 8.

Discussion:

This area had a small rat population. Many stations showed no acceptance at first. It was several days before the rats would eat much of the unpoisoned bait. Bait consumption showed a gradual increase for 10 days or more. The average daily acceptance from 24 active stations reached 74 grams. When the poisoned bait was substituted the average consumption in grams for the first night dropped to 43¼ grams in 18 active stations. This decline was heavier than expected and there was no further acceptance after the first night.

As these stations were in one continuous line along wasteland, the consumption of unpoisoned oats continued to increase slowly over a long period, as rats were being drawn from more distant cover on either side of the route. This later proved contrary to the usual experience found when the stations were distributed evenly throughout the field; and where consumption reached a maximum in about one week with little further increase after that time. These tests were sufficiently encouraging to warrant further study on a larger scale.

WAIPIO SUBSTATION

After the apparent success of the preliminary tests at the Kailua substation in October 1936, a more comprehensive field test (Experiment No. 31) was started on January 5, 1937, at the Waipio substation in an area of big cane reported to be rat infested. Rolled oats containing a small amount of corn oil attrahent were used as the bait. Thallium sulphate at the rate of 1-100 was used in the poisoned oats.

This experiment was observed daily except Sundays for 19 days. The summary of the data obtained is presented in Table VII.

TABLE VII

SUMMARY OF PREBAITED FEEDING STATIONS—WAIPIO SUBSTATION, EXPERIMENT NO. 31

Rolled oats placed in first set of 48 stations January 5 and 6, 1937
Rolled oats placed in second series of 50 stations alternating with the first 48 on January 12 and 14, 1937

		Unpoisoned oats												Poisoned oats (1-100)			
Dates—January 1937		6	7	8	9	11	12	14	15	16	18	19	20	21	22	23	25
Interval between visits (days)		1	1	1	1	2	1	2	1	1	2	1	1	1	1	1	2
Total stations placed		26	48	48	48	48	48	74	98	98	98	98	98	98	98	98	98
No. of stations showing no acceptance	1st 48 stations	15	19	8	2	2	1	0	0	0	0	0	0	0	30	45	46
	2nd series of 50							6	7	5	0	0	0	1	12	49	50
No. of stations showing acceptance	1st 48 stations	11	29	40	46	46	47	48	48	48	48	48	48	48	18	3	2
	2nd series of 50							20	43	45	50	50	50	49	12	1	0
Total oats eaten (grams)	1st 48 stations	278	641	880	1504	4075	3973	2576	2174	2525	3944	2582	2945	2480	352	23	10
	2nd series of 50							329	936	1010	3144	1663	2225	1447	176	5.7	0
Avg. acceptance per active station between readings (grams)	1st 48 stations	25.3	22.1	22.0	32.7	88.6	84.5	53.7	45.3	52.6	82.2	53.8	61.4	51.7	19.5	7.6	5
	2nd series of 50							16.5	21.8	22.4	62.9	33.3	44.5	29.5	14.6	5.7	0
Avg. daily acceptance per active station (grams)	1st 48 stations	25.3	22.1	22.0	32.7	44.3	84.5	26.9	45.3	52.6	41.1	53.8	61.4	51.7	19.5	7.6	2
	2nd series of 50							8.3	21.8	22.4	31.5	33.3	44.5	29.5	14.6	5.7	0
Total eaten (pounds)	1st 48 stations					(61.65 lb—15 days)								(6.31 lb—5 days)			
	2nd series of 50					(20.51 lb— 8 days)								(3.59 lb—5 days)			
Total consumed during each interval (pounds)	1st 48 stations	.61	1.41	1.94	3.31	8.98	8.77	5.68	4.79	5.56	8.69	5.69	6.49	5.46	.78	.05	.02
	2nd series of 50							.73	2.06	2.23	6.93	3.66	4.90	3.19	.39	.01	0
Avg. daily consumption (pounds)	1st 48 stations	.61	1.41	1.94	3.31	4.49	8.77	2.84	4.79	5.56	4.35	5.69	6.49	5.46	.78	.05	.01
	2nd series of 50							.37	2.06	2.23	3.47	3.66	4.90	3.19	.39	.01	0

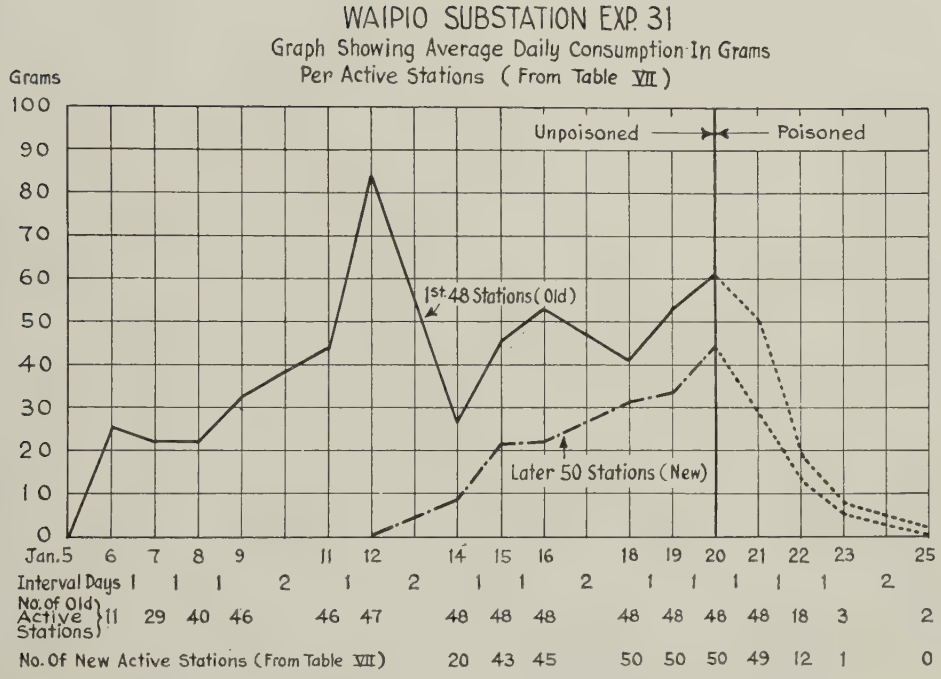

WAIPIO SUBSTATION EXP. 31
Graph Showing Average Daily Consumption In Grams
Per Active Stations (From Table VII)
Grams
Unpoisoned
Poisoned
1st. 48 Stations (Old)
Later 50 Stations (New)
Jan. 5 6 7 8 9 11 12 14 15 16 18 19 20 21 22 23 25
Interval Days 1 1 1 2 1 2 1 1 2 1 1 1 1 1 2
No. of Old Active Stations 11 29 40 46 46 47 48 48 48 48 48 48 48 18 3 2
No. Of New Active Stations (From Table VII) 20 43 45 50 50 50 49 12 1 0

Fig. 9.

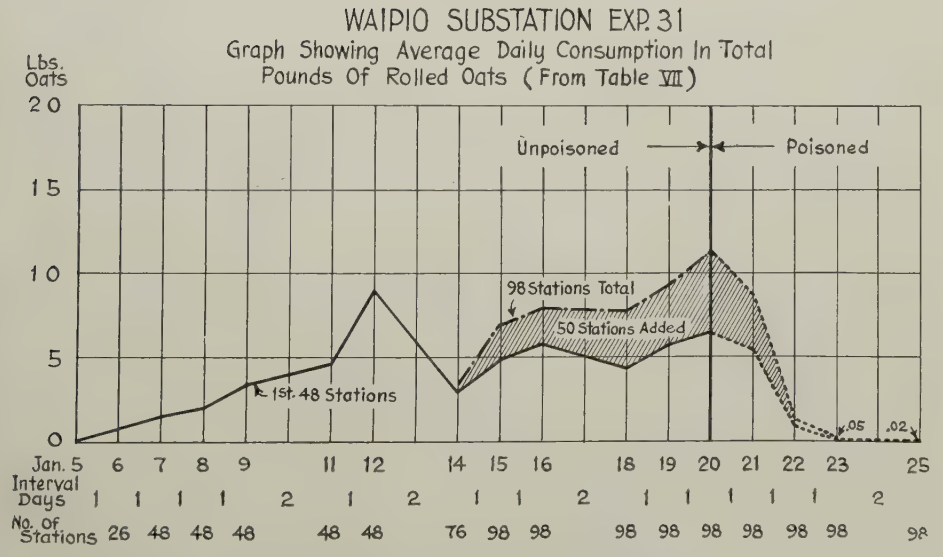

WAIPIO SUBSTATION EXP. 31
Graph Showing Average Daily Consumption In Total
Pounds Of Rolled Oats (From Table VII)
Lbs. Oats
Unpoisoned
Poisoned
98 Stations Total
50 Stations Added
1st. 48 Stations
.05
.02
Jan. 5 6 7 8 9 11 12 14 15 16 18 19 20 21 22 23 25
Interval Days 1 1 1 1 2 1 2 1 1 2 1 1 1 1 1 2
No. of Stations 26 48 48 48 48 48 76 98 98 98 98 98 98 98 98 98

Fig. 10. First 48 stations shown by solid line. Later 50 stations were added (shaded area above solid line) making a total of 98 stations shown from June 14 to 23, 1937.

Discussion:

This experiment offered an opportunity to test further the various types of covers and pans for the feeding stations. The simplest curved galvanized iron cover proved to be the best. Only 48 stations were operated for the first seven days. These were widely spaced in most instances to discover where the rats were living and to determine if they could be drawn to the food.

In a few days these stations became very active with the average daily consumption per station rising to 84 grams of unpoisoned oats on the seventh day. Fifty new stations were then placed in the same area, alternating with the original 48, reducing the spacing to about 80 or 100 feet, and increasing the total number of stations to 98. The immediate result was a heavy drop in the average consumption from the old stations of from 84½ to 27 grams, with only 20 new stations becoming active, averaging 8 grams for their first 2 days. This was a net reduction of 63.4 per cent in the total consumption for the field. This is graphically shown in the chart in Fig. 10 under the dates of January 12 to 16. We have been unable to give a positive explanation of this heavy drop in total consumption. It would be necessary to repeat this test to determine if it was more than a coincidence. One might conclude that the addition of these 50 stations to the same area was a disturbing factor which confused the rats and caused them to be suspicious of all stations including the particular ones that they had been in the habit of visiting previously. If there is any significance in this occurrence it suggests that the desired number of stations in a particular area be started all at one time and that no changes in location of stations within the area be made after the first day.

The total consumption for the field had almost returned to normal in three days, with the new stations receiving less attention than the old stations.

Unpoisoned oats were exposed in all stations for 8 days after which time poisoned oats were substituted. The average consumption from the old stations dropped 14.7 per cent from 61 grams for the last night of unpoisoned oats to 52 grams for the first night of poisoned oats. At the same time the new stations dropped 32 per cent from 44½ grams each of unpoisoned oats to 29½ grams of poisoned oats. (See Table VII and Figs. 9 and 10.)

Of the total amount of poisoned oats eaten, 87.6 per cent were eaten on the first night of exposure, 12 per cent on the second night, with only .4 of one per cent on the third and fourth nights combined, after which time no more poisoned oats were taken. Ninety-seven out of the 98 stations were visited on the first night of poisoned oats, 30 stations were revisited on the second night and only 4 on the third and 2 on the fourth nights, after which all stations remained undisturbed. The amounts consumed at these 6 stations on the third and fourth nights were so small that it could scarcely be measured but it was estimated at 5 grams each. The smell of dead rats in the field was reported by the field personnel.

Unpoisoned grain was again placed in all 98 stations twelve days after the first poisoning. There was a slight disturbance of the grain in 13 stations but the amount of oats missing was too small to measure in the field. This indicated that only a few stray mice or rats had escaped the poison campaign or had later migrated into the treated area.

WAIMANALO SUGAR COMPANY

Early in January 1937, Manager Bennett, of the Waimanalo Sugar Company, discovered that rats (determined to be *hawaiiensis*) from the forest area above Waimanalo, had invaded and were doing great damage to some small blocks of 31-1389 cane. These areas offered an excellent opportunity for trying out the feeding-station method of rat control on a larger scale and under wet conditions.

Accordingly, an experiment (No. 30) was installed in this area consisting of 116 stations spaced 60 to 90 feet apart along roads and ditches, at the edge of Panicum grass along a reservoir, and along a stream. Only in a few cases was it deemed necessary to go into big cane to place the stations. Various types of tin pans and covers were used but the most satisfactory station consisted of a "covered-wagon" type of cover placed over a small square baking pan. Other types of covers and pans which would not nest together, proved very troublesome and bulky to handle. The bait used was rolled oats with about one quart of corn oil mixed with each 10-12 pounds of oats, both unpoisoned and poisoned. The poisoned oats were treated at the rate of one pound thallium sulphate to 100 pounds of rolled oats. Unpoisoned oats were fed for seven days followed by poisoned oats. Notes were taken after 2 days of poisoned oats and again after 7 days. Unpoisoned oats were again returned to all stations for 8 days as a check on the effectiveness of the poisoned oats.

The detailed consumption data were tabulated and summarized. Only the summarized data are presented in Table VIII.

TABLE VIII

SUMMARY OF PREBAITED FEEDING STATIONS—WAIMANALO SUGAR COMPANY, EXPERIMENT NO. 30

Rolled oats placed in 116 stations on January 25, 1937

	Unpoisoned oats				Poisoned oats (1-100)		Unpoisoned oats
Dates—1937	Jan. 27	29	30	Feb. 1	3	8	16
Interval between visits (days)	2	2	1	2	2	5	8
Total stations placed	92	116	116	116	116	116	116
Number of stations showing no acceptance	7	5	10	2	17	89	99
Number of stations showing acceptance	85	111	106	114	99	27	17
Total oats eaten (grams)	4,851	9,867	6,156	9,785	2,281	329	217
Average acceptance per active station between readings (grams)	64.8	88.9	58.1	85.8	23.1	12.2	12.8
Average daily acceptance per active station (grams)	32.4	44.4	58.1	42.9	23.1	12.2	1.6
Total eaten (pounds)	(68.9 lbs.—7 days)				(5.75 lbs.—7 days)		(0.48 lbs.—8 days)
Total consumed during each interval (pounds)	12.1	21.7	13.6	21.5	5.0	0.75	0.48
Average daily consumption (pounds)	6.1	10.9	13.6	10.8	Total only 5.0	0.75	.06

Ratio of poisoned to unpoisoned oats 1:12

The average daily consumption in total pounds of oats eaten in 116 stations is plotted in Fig. 11.

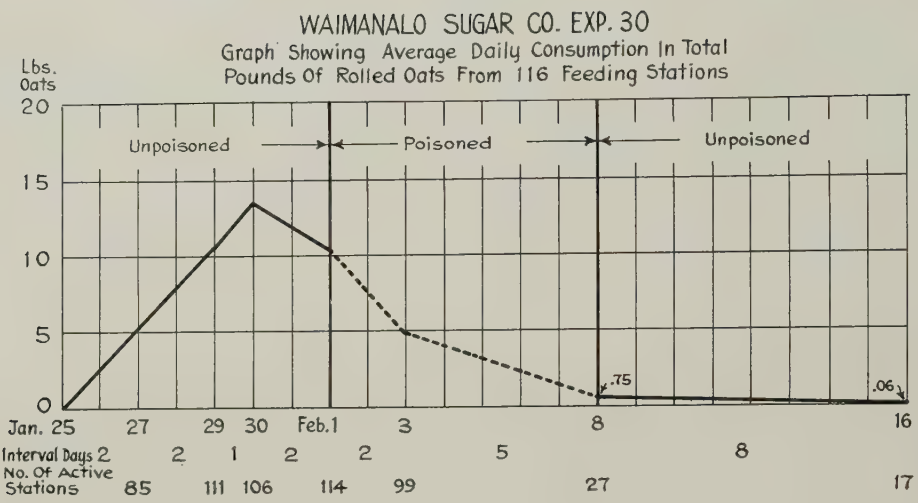


Fig. 11.

Discussion:

Contrary to previous experience, good consumption of unpoisoned oats was obtained on the second day, and this did not increase after the fifth day. This was probably due to the less suspicious nature of the small native Hawaiian rat, who is reputed to take poisoned food more readily than other more cautious species.

The drop in the consumption curve on February 1, just prior to poisoning was due to the fact that there was not enough bait placed in the pans to feed the rats for two days. This resulted in many empty pans before the rats had obtained their fill.

When poison was applied, 15 active stations became inactive and the average consumption per station dropped to 53.6 per cent of the last 2 days of unpoisoned oats. We cannot explain this drop unless it was due to the high concentration of thallium affecting the rats so quickly that they could consume but a small amount of the poisoned oats. But as a lesser amount was required to kill,* the bait was still effective (see Table VIII) as dead rats were easily found over the area beginning on the second day. From these results the use of a high concentration (1-100) of poison may be open to question when used in feeding stations.

For the purpose of checking on the effectiveness of the poison, unpoisoned grain was again placed in all stations, seven days after any remaining poisoned oats had been removed. The results showed a very small consumption in only 17 stations out of the original 116, all of which were located on the margin of the unpoisoned area. This indicated that the poison was effective within the area.

On account of wet weather (19½ inches of rain) during this test, oats left untouched after 3 or 4 days showed varying degrees of mold, depending on air circulation around the individual stations. From a few less active stations it was occasionally necessary to discard a small amount of dirty and powdered oats, but very few oats were wasted and no spoilage occurred at the active stations. Poisoned oats should be either collected or discarded after 3 or 4 days exposure during wet weather.

* Upon dissecting a poisoned rat from the "K" reservoir area, it was found that the poisoned oats eaten were about equal in volume to a good-sized garden pea.

KILAUEA SUGAR PLANTATION COMPANY

Two extensive tests with prebaited feeding stations were conducted at Kilauea Sugar Plantation Company. These studies were made in big cane on a much larger scale than had been possible at any time previous. Both tests were visited oftener and continued longer, than would be necessary for a practical control, for the purpose of determining what was happening in each field.

(*Kilauea Experiment No. 1.*) The area chosen (Field 20) for this first experiment contained 45 acres of POJ 2878 and 34 acres of Badila, all one year old. Two hundred and fifty-five feeding stations of the standard type previously described were placed in this field on April 10th. Later, 32 additional stations were placed in certain areas purposely omitted previously in order to determine a proper spacing between stations. The total stations placed in the field amounted to 287 which was an average of 3.6 stations per acre. Raw linseed oil was rubbed on the inside of each cover as an attrahent when they were first placed in the field. Poisoned and unpoisoned oats were used in these stations as follows:

(1) 6 days with unpoisoned oats; (2) 6 days with poisoned oats; (3) 4 days with unpoisoned oats, for a second time; and (4) 2 days with poisoned oats, a second time.

The detailed consumption by stations was carefully tabulated and summarized. The summarized data are presented in Table IX.

TABLE IX

SUMMARY OF PREBAITED FEEDING STATIONS—KILAUEA SUGAR PLANTATION COMPANY, FIELD 20, EXPERIMENT 1

Rolled oats* placed in 255 stations on April 10, 1937

	Unpoisoned oats			Poisoned oats (1–250)		Unpoisoned oats	Poisoned oats (1–250)
Dates—April 1937	12	14	16	19	22	26	28
Interval between visits (days)	2	2	2	3	3	4	2
No. of stations showing no acceptance	168	9	0	9	233	218	246
No. of stations showing acceptance	84†	243†	252†	243†	19	34	6
Total oats eaten (grams)	2,302	20,390	26,292	10,950	101	504	41
Avg. acceptance per active station between readings (grams)	27.4	83.9	104.3	42.9	5.2	14.8	6.8
Avg. daily acceptance per active station (grams)	13.6	42.0	52.2	42.9	5.2‡	3.4	3.4
Total eaten (pounds)	(108 lbs.—6 days)			(24.34 lbs.—6 days)		4 days 1.1	2 days 0.09
Total consumed during each interval (pounds)	5.1	44.9	57.9	24.12	.22	1.1	0.09
Avg. daily consumption (pounds) (252 stations)	2.5	22.5	29.0	24.12 Total only‡	.22	.27	0.09

Ratio of poisoned to unpoisoned oats 1:4.4

* Coconut oil used with both unpoisoned and poisoned oats, approximately one quart to fifteen pounds of oats.

† Three stations omitted because records were lost on second day of poisoning due to a five-inch rain which washed out the stations.

‡ When poison was applied, 87 to 90 per cent was consumed the first night with a rapid decrease each succeeding night, so total only can be shown. Poisoned rats cannot return to eat the following day.

Discussion:

After the first two days exposure of unpoisoned grain only one-third of the stations showed any activity, with an average of only 13.6 grams of oats consumed per active station. Many tracks of mice were noted, but few evidences of rats. Even when the stations were deliberately placed on a fresh rat trail coming out of the gulch cover, few or no oats were eaten. In four days, however, all but 9 stations out of the total of 255 had become active with an average daily consumption of 42 grams for each. Those stations located on fresh rat trails from the gulch were now among the most active stations in the field. After two more days exposure (total 6 days) all stations (no exceptions) had become active with an average daily acceptance of 52 grams per station. In a few cases rats dug tunnels under emptied pans in an attempt to locate additional food. In one case a fresh hole had been dug next to the station, indicating a desire to live close to the source of the new food. When poison was applied, 9 stations became inactive leaving 243 with an average consumption of 43 grams, a decline of 9 grams or 17 per cent from the best day of unpoisoned acceptance. This decline in consumption on the night of substituting the poisoned grain has always occurred and varies only in degree. The cause is not known. It may indicate a certain degree of detection of the poison or merely that the rats cannot eat as much of the poisoned as unpoisoned oats during one night. Perhaps ill effects following their first visit early in the evening, prevents them from eating again before hiding for the following day. As the rats were able to visit and eat poison but once, most of the poisoned oats were consumed on the first night of poisoning, although the figure obtained covered 3 nights. Three stations were discarded due to a heavy rain which completely flooded them the second day of poisoning.

The average daily total consumption of unpoisoned oats in 252 stations for 6 days follows: first 2 days, 2.5 pounds; third and fourth days, 22.5 pounds; fifth and sixth days, 29 pounds, making a total of 108 pounds of unpoisoned oats eaten during prebaiting. During the following 6 days, 24.3 pounds of poisoned oats were eaten, indicating a ratio of 4.4 pounds of prebait eaten for each pound of the poisoned food.

For the purpose of experiment the poison was left in the field a second period of three days after the first record of poison had been taken. Only 19 stations or 7¾ per cent showed any further disturbance of the poisoned grain, with only a total measured amount eaten of .22 pound or 9/10 of one per cent of the amount eaten in the first three days of poison. It therefore seems questionable whether it is worth while to leave the poison in the field the extra three days. It is quite probable that most or all of this small consumption occurred on the fourth night immediately following the first record.

The average daily consumption of rolled oats in pounds (Table IX) for the entire test is shown graphically in Fig. 12.

Distribution of Rat Population:

The detailed data, station by station, have been plotted on the map of the field shown in Fig. 13. A large dot was placed on this map for each 1/40 pound or 11.3 grams of poisoned oats consumed. This amount is a lethal dose for 3.4 pounds of rats and could account for 3 or 4 average rats and allow a margin for some of them

KILAUEA SUGAR PLANTATION CO.

FIELD 20

Rat Control – Showing numbered feeding stations with amounts of poison consumed

LEGEND

● = 11 Gms. Poisoned Oats Eaten

• = 5½ " " " "

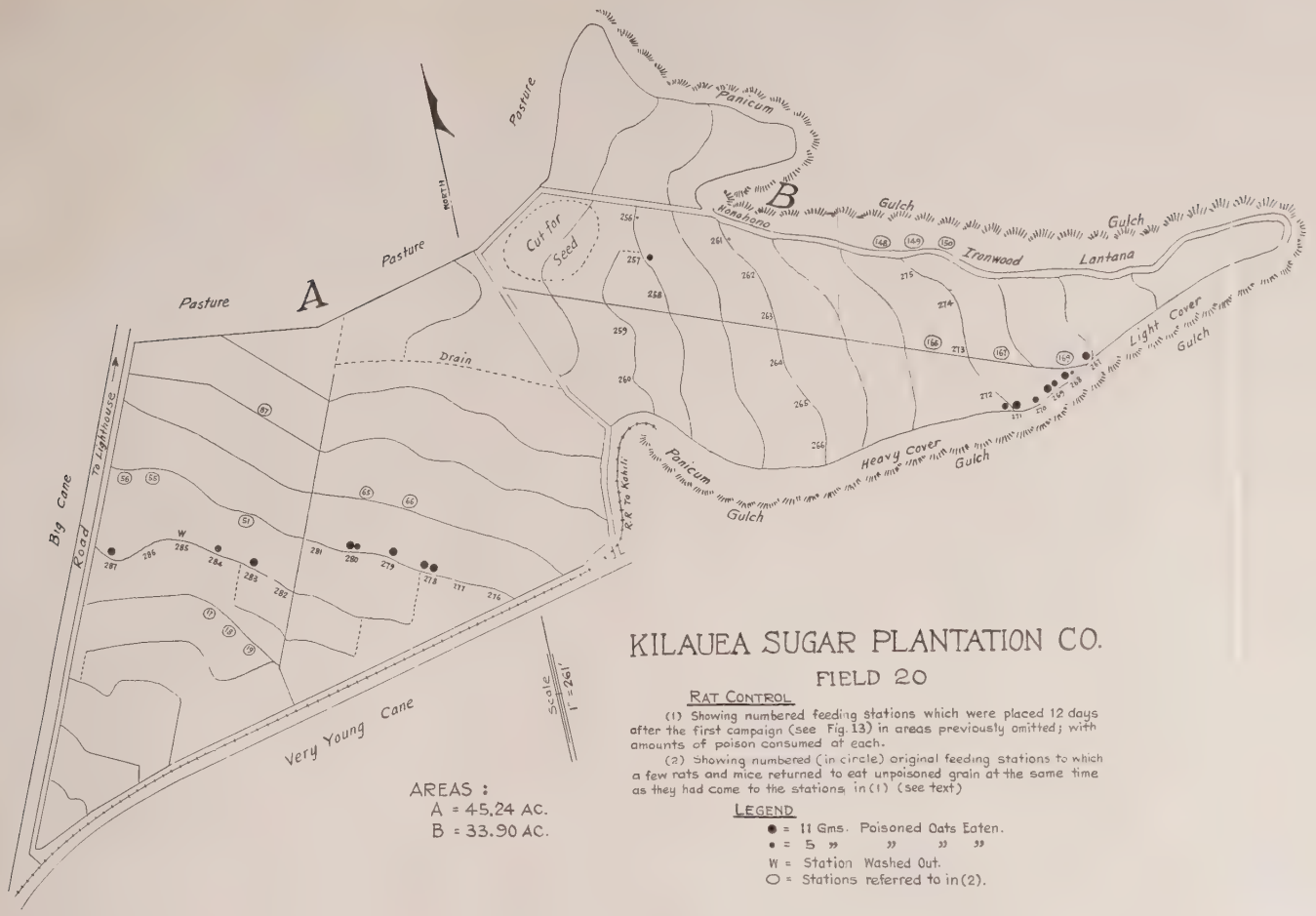
W = Station Washed Out.

AREAS :

A = 45.24 AC.

B = 33.90 AC.

Fig. 13.



KILAUEA SUGAR PLANTATION CO.

FIELD 20

RAT CONTROL

(1) Showing numbered feeding stations which were placed 12 days after the first campaign (see Fig. 13) in areas previously omitted; with amounts of poison consumed at each.

(2) Showing numbered (in circle) original feeding stations to which a few rats and mice returned to eat unpoisoned grain at the same time as they had come to the stations in (1) (see text)

LEGEND

● = 11 Gms. Poisoned Oats Eaten.
• = 5 " " " "
W = Station Washed Out.
○ = Stations referred to in (2).

Fig. 14.

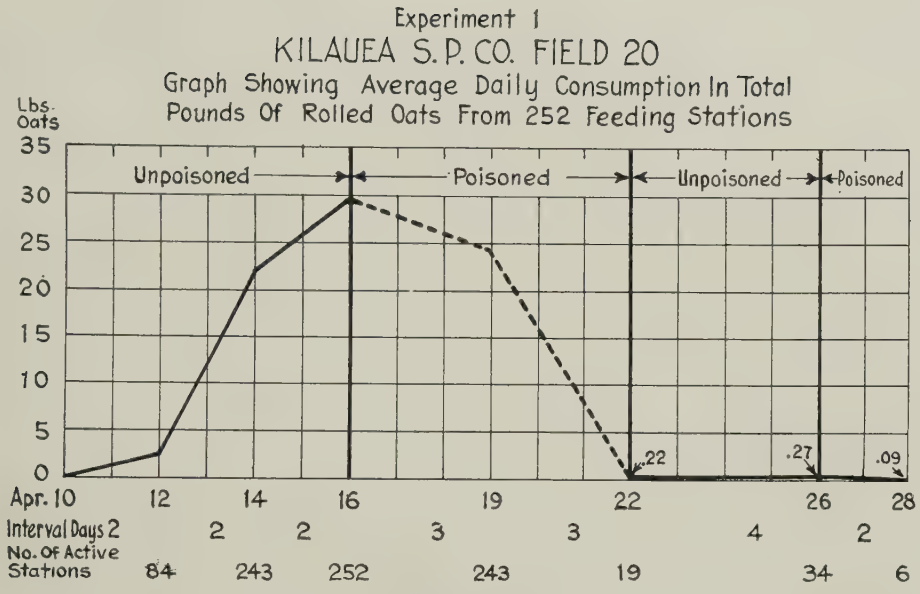


Fig. 12.

to eat more than the minimum lethal dose. By this method a graphic picture is presented of the distribution of the rats in the field in relation to natural cover occurring around the field.

The areas along the clean open pasture and young cane harbored comparatively few rats. An extremely heavy infestation occurred along the gulches where the natural cover of Panicum grass, honohono, morning glory and lantana make the area almost impenetrable. Along this area there were many distinct and clear-cut, rat trails through the grass from the gulch direct into the cane. The greatest damage to cane invariably occurred at the heads of the small gullies or field drains.

A Study of Distance Between Stations:

Four level ditches and a 350-foot strip along the gulch were purposely omitted in the first poisoning. These areas are blank on the map in Fig. 13. All of the poisoned oats were picked up and unpoisoned oats substituted in all 255 stations on April 22nd. On this same day 32 new stations were placed in these four level ditches and the 350-foot strip along the gulch which had been omitted in the original placement. These were filled with unpoisoned oats also. On April 26 all stations in the field, including the 32 new ones, were filled with poisoned oats. Two days later (April 28) the amount of consumption was measured and recorded. The results are summarized in Table X and plotted on the map in Fig. 14.

TABLE X

SUMMARY OF PREBAITED FEEDING STATIONS IN AREAS PREVIOUSLY OMITTED
Oats put out April 22, 1937

	Unpoisoned oats	Poisoned oats (1-250)
Dates—April 1937	26	28
Interval between visits (days)	4*	2
Total stations placed†	31	31
Number of stations showing no acceptance	8	17
Number of stations showing acceptance	23	14
Total oats eaten (grams)	1362	154.4
Average acceptance per active station between readings (grams)	59.2	11.0‡
Average daily acceptance per active station (grams)§	14.9	11.0‡
Total eaten (pounds)	3	.34‡
Total average daily consumption (pounds)	.75	.34‡
Ratio: Poisoned to unpoisoned 1:8.8		

* Poisoned at end of 4 days prebait to save time, as very little activity was evident in these areas.

† One station in low spot lost by flooding.

‡ 85 to 90 per cent of the poisoned oats were eaten the first night, so only totals are shown.

§ The decline in daily consumption when poison was applied amounted to 14.9—11.0=3.9 or 26 per cent below the average consumption of all 4 days of prebait.

The final acceptance of poisoned oats in these level ditches was very small as compared with the original acceptance in the field as a whole. Relatively few rats and mice were left in the level ditches which had not been treated originally. This indicates that a large number of the rats originally in this area were drawn greater distances to the original stations in the adjacent level ditches (see Fig. 14). There remained a few rats and mice who had escaped the first poisoning because of this increased distance between the original lines of stations. Judging from the results obtained in this test, we cannot expect complete control when the lines of feeding stations are spaced 250 feet or more apart, without greatly increasing the length of the unpoisoned feeding period.

Unpoisoned Oats Following the Poisoned:

After the 6 days of poisoning, unpoisoned rolled oats were again exposed for four days in all stations. There were 34 stations (13 per cent) in which the oats had been disturbed or some slight amount eaten during this four-day period. A total of 1.1 pounds of unpoisoned oats was eaten, averaging .27 pound per day, or slightly over one per cent of the average daily amount consumed before poisoning. Judging from the size of the droppings left, mice or young rats were the chief survivors.

These stations showing a return of rodents were plotted on the map (indicated stations enclosed in circle in Fig. 14) and were found to be in groups on the edge of the areas omitted in the first poisoning. (See Stations 17, 18, 19; 55, 56; 65, 66; 165, 167, and 169.) At these points the station routes were 350 or more feet apart. This evidence shows that some rats had been left in the wider areas omitted in the first poisoning. One remaining group of stations (148, 149, and 150) was located

along the gulch next to an unpoisoned area. Here again, rats survived where the spacing between stations was too great. It is possible that young rats just past the weaning stage, traveling in a wider circle each day, had at last moved far enough from their nest to contact one of these feeding stations.

Poisoned oats were again* (April 26) placed in all (34) stations showing the slightest disturbance of the unpoisoned oats during the four-day period. Only 6 stations showed a measurable consumption, a total .09 pound or less than 4/10 of one per cent of the amount of poison eaten originally which was negligible.

Cost of Poisoning:

There were 284 stations in this 79-acre field which is an average of 3.6 stations per acre. Excluding the cost of car transportation to and along the field roads and the investment in equipment, a 9-day schedule of visitation of an average of 3.6 to 4 stations per acre may be summarized as follows:

Labor†:

1st trip—Distributing the stations, about (should place about 20 stations per hour)	16 hours
2nd trip—Refilling the stations, 4 days later, about (should cover 22-25 stations per hour)	11 hours
3rd trip—Poisoning the stations, about (2 to 3 days later)	13 hours
4th trip—Picking up stations, about (3 or 4 days later)	13 hours
Total	52 hours
Labor (conservative estimate)	$10.40
Unpoisoned oats—110 pounds at 4 cents per pound	4.40
Poisoned oats—25 pounds at 13 cents (1-250)	3.25
Coconut oil—3 gallons at $1.00	3.00
Total cost of labor and materials to treat 79 acres	$21.05
Total cost of labor and materials to treat 1 acre	$ .266

This cost figure would be subject to fluctuation according to local conditions but compares very favorably with previous methods which used the torpedo or sausage bait.

Summary:

These studies confirm our previous findings and prove that the rats at Kilauea respond to the feeding-station method in a satisfactory manner, as they did on Oahu plantations.

* This is the same time that poison was placed for the first time in the 32 new stations which had been purposely omitted, to study the distances rats could be drawn.

† Wet cane greatly reduces labor efficiency in caring for the feeding stations.

The greatest concentration of rats occurs along the gulches and wasteland where permanent cover is always present. This suggests that an early intensive campaign be concentrated along natural rat harbors near young cane. The feeding-station method is especially adapted to this scheme of control.

From the results of this test we cannot expect complete control when the lines of feeding stations are spaced 250 feet or more apart, without greatly increasing the length of the prebaited feeding period.

For practical purposes 3 days exposure of poison is sufficient as only one per cent additional oats was eaten during the second three-day period.

After 6 days of poisoning, a return to unpoisoned grain gave consumption of only one per cent of the original average daily amount, showing a very small remaining population, which would not warrant an immediate re-poisoning. It would be more practical to repeat the treatment in 2 to 3 months, giving the small rats a chance to grow up enough to travel, but before another generation of young had developed.

The cost of labor and materials, excluding transportation and investment in equipment, need not rise above 30 cents per acre for one poisoning. This charge would cover the installation and necessary visitations of an average of 4 stations per acre for a period of 9 days.

Fig. 15. Typical Panicum grass-covered drain in Field 1, Kilauea Sugar Plantation Company where Experiment No. 2 was carried out. This excellent rat harbor was heavily infested following the harvesting of adjacent cane areas.

Fig. 16. Edge of Panicum grass-covered drain in harvested area of Field 10 showing feeding stations being placed. The consumption of the active stations just previous to poisoning amounted to an average of 80 grams per night which was the highest for any field studied so far. This indicated an abundance of rats as these stations were spaced only 40 feet apart.

(*Kilauea Experiment No. 2.*) The purpose of Experiment No. 2 was to draw the rats out of a field drain or gulch between Fields 10 and 1. The cane in these fields had been harvested about April 1 and the rats from the cane had been forced to move into the heavy growth of Panicum in large numbers. Their presence was definitely indicated by much freshly eaten waste cane left along the edge of the field. Two small, direct-poison skirmish tests using sausages, oat briquettes, and loose oats placed in standard feeding stations resulted in very poor acceptance. Trapping was resorted to beginning April 15, by K. Harada, agriculturist, Kilauea Sugar Plantation Company. His catch in traps, spaced 20-25 feet apart was good, ranging from 15 to 20 rats per 100 trap-days. After 10 days the traps were moved farther down the gulch toward the sea and a set of 59 feeding stations, spaced 40 feet apart was placed along the edge of the Panicum grass cover (see Fig. 15). These stations were kept filled with unpoisoned oats for 7 days followed by poisoned oats for 7 days. Unpoisoned oats were again placed in the stations and observed after 3 days to check the thoroughness of the poisoning.

The data were recorded, station by station, and the summary is given in Table XI.

TABLE XI

SUMMARY OF PREBAITED FEEDING STATIONS—KILAUEA SUGAR PLANTATION COMPANY, FIELD 10, ALONG DRAIN, EXPERIMENT 2

Rolled oats placed in 59 stations on April 26, 1937

	Unpoisoned oats			Poisoned oats (1-250)		Unpoisoned oats
Dates—1937	Apr. 30	May 1	3	6	10	13
Interval between visits (days)	4	1	2	3	4	3
Number of stations showing no acceptance	11	4	2	2	53	54
Number of stations showing acceptance	48	55	57	57	6	5
Total oats eaten (grams)	4,239	4,163	9,149	3,382	40	120
Average acceptance per active station between readings (grams)	88.3	75.6	160.5	59.4	6.8	23.8
Average daily acceptance per active station (grams)	22.0	75.6	80.2	59.4	6.8	7.9
Total eaten (pounds)	(38.6 lb—7 days)			(7.53 lb—7 days)		(.25 lb—3 days)
Total consumed during each interval (pounds)	9.3	9.2	20.15	7.45	.08	.25
Average daily consumption (pounds) (59 stations)	2.3	9.2	10.1	See above		.08

Ratio poisoned to unpoisoned oats 1:5.3

The average daily consumption in total pounds of oats eaten in 57 stations is plotted in Fig. 17.

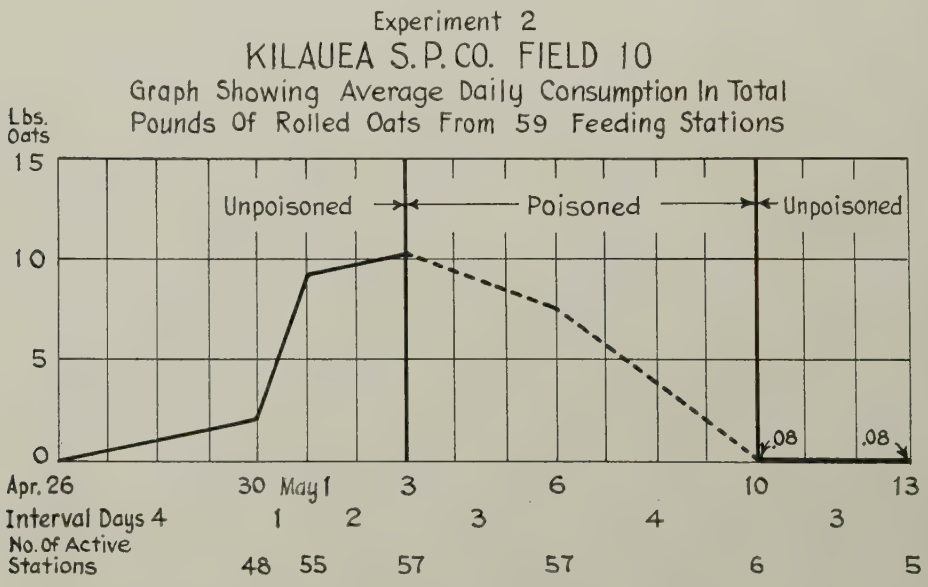


Fig. 17.

Discussion:

Typical of all prebaited feeding tests, the number of active stations as well as the average consumption per station increased rapidly for 5 or 6 days then materially lessened as maximum consumption was approached. Only two stations remained inactive throughout, due to a poor guess in placement.

The consumption of the active stations just previous to poisoning amounted to an average of 80 grams which was the highest for any field studied so far. This indicated an abundance of rats when we realize that these stations were only 40 feet apart.

When poison was applied there was a drop in consumption of 2.5 pounds or 25 per cent under the maximum of 10.1 pounds of the preceding day. This is a greater decline than in the preceding test but we have no proven explanation. It should be noted that there was almost no poison consumption after the third day of poison. This test gave further evidence that 3 or 4 days exposure of poison was sufficient.

Unpoisoned grain was again returned to prove the effectiveness of the poison. Only four stations showed a measurable consumption for the 3 days, averaging only 8/100 pound per day or 8/10 of one per cent of the daily consumption before poisoning. This indicated that very few mice or rats still existed in the treated area or had come from greater distances to the food. This border effect by stray rats will be less when the treated areas are in larger units.

After efforts of direct poisoning (Skirmish Tests 1 and 2) were ineffective, and even following intensive trapping for several days, this group of feeding stations, closely spaced along the field drain covered with Panicum grass, adjacent to a recently harvested field, still gave the highest average consumption of poison per station of any test that we have conducted so far.

GROVE FARM COMPANY, LTD.

Field 23 consisting of 142.7 acres of one-year old, unirrigated Yellow Tip cane was chosen as the site for the field test at Grove Farm Company. Between March 29 and April 2, 1937, ten half-bags of crushed oat torpedoes had been scattered, particularly along the edges of the field, roads, and trails. These torpedoes were much in evidence everywhere that feeding stations were placed. Three hundred and twenty-eight stations were spaced from 60 to 100 feet, depending on location. The spacing was reduced to 60 feet in some places where heavy vegetation adjacent to damaged cane indicated an abundance of rats. Many of the feeding station covers used in this test were heavy pieces of galvanized roofing which proved very awkward and expensive to carry into the field or along wasteland. Raw linseed oil was rubbed on the inside of each cover as an attrahent when they were placed in the field.

As this field was unirrigated and carried cane one year old, it was impossible to place stations inside the cane away from roads or trails. The large solid blocks of cane were inaccessible, so the stations had to be placed mostly around the edges and along the roads and on a few trails. On this account the distribution of stations averaged only 2.3 per acre, although we aimed to have about 4 stations per acre. Poisoned and unpoisoned oats were used in these stations beginning April 9 and 10 as follows:

(1) 3 days with unpoisoned crushed oats; (2) 8 days with unpoisoned rolled oats; (3) 8 days with poisoned rolled oats; and (4) 5 days with unpoisoned rolled oats a second time.

The detailed consumption by stations was carefully tabulated and summarized. The summary data are presented in Table XII.

TABLE XII

SUMMARY OF PREBAITED FEEDING STATIONS—GROVE FARM COMPANY, LTD., FIELD 23

Crushed oats put out April 9-10
Changed to rolled oats April 13
Total=328 stations

	Unpoisoned oats					Poisoned oats (1-250)		Unpoisoned oats
Dates—1937	Apr. 13	15	17	19	21	24	29	May 4
Interval between visits (days)..	3	2	2	2	2	3	5	5
Number of stations showing no acceptance	322	264	175	137	56	88	289	159
Number of stations showing some acceptance	5	54	153	191	272	240	39	169
Total oats eaten (grams).....	74.0	2,208	9,940	13,966	29,165	6,316	316	2,942
Avg. acceptance per active station between readings (grams)	15.0	40.9	64.9	73.1	107.3	26.3	8.1	17.4
Avg. daily acceptance per active station (grams)	4.5	20.4	32.5	36.5	53.6	26.3	8.1	3.5
Total oats eaten (pounds).....		(121.7 lb—11 days)				(14.6— 8 days)		(6.5— 5 days)
Total oats eaten during each interval (pounds)	.16	4.8	21.9	30.8	64.2	13.9	0.7	6.5
Avg. daily consumption (pounds)	.05	2.4	10.9	15.4	32.1	13.9	0.7	1.3
						14.6 lb		

The average daily consumption of rolled oats in pounds is shown graphically in Fig. 18.

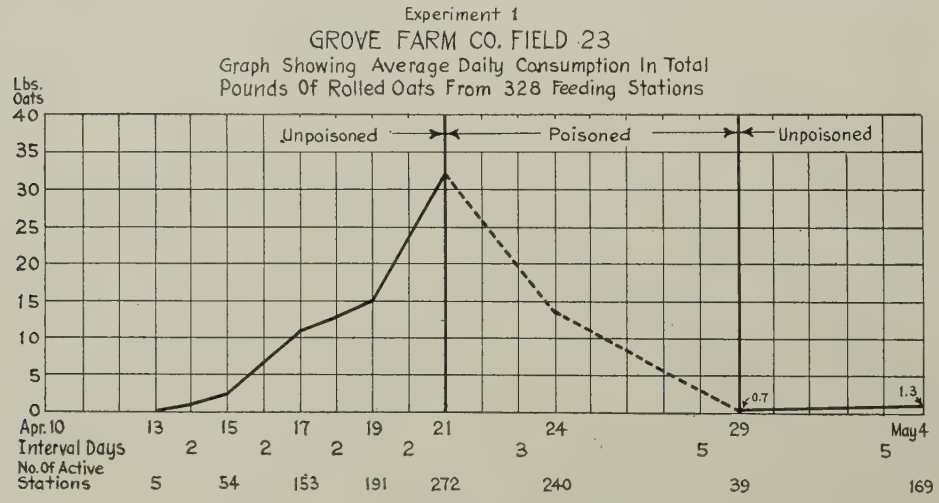


Fig. 18.

Discussion:

Due to difficulty in securing rolled oats when this test was first installed, crushed instead of rolled oats were used so that the test could begin promptly on April 9 and 10th. However, this substitution proved to be a waste of time. Only 5 stations in the entire field showed any consumption of these crushed oats during the first 3 days of exposure; then, all stations were changed to rolled oats. After 6 days with rolled

GROVE FARM CO.
FIELD 23
SCALE 1 in. = 300 ft.
AREA: 142.7 Acres
LEGEND
● = 11 Gms. Poisoned Oats Eaten
• = ½ Of Above Amount
True North
Reservoir
Honohono
Reservoir
Honohono
Reservoir
Trees
Bushes
OLD GOVERNMENT ROAD
FIELD ROAD
WASTELAND TREES
WASTELAND TREES
WASTELAND TREES
Honohono
Stream
Honohono
Swampy
Gulch
Honohono
Stream
Panicum
Gulch – Ironwoods Panicum & Honohono Gulch
R.R. Track
To Mill

oats, 55 per cent of the stations were active with an average daily consumption of 36.5 grams. However, between the sixth and eighth day, the total consumption in the field doubled, 272 stations (83 per cent) being active with an average daily consumption of 54 grams. The other 56 stations were located in areas apparently free of rats.

Poison was finally applied to all active stations after 8 days of unpoisoned rolled oats. Poisoned oats consumption amounted to a total of 14.6 pounds eaten in 240 stations and represented a heavy decline from the peak of 32.1 pounds average for the previous 2 days (see Table XII). This slump is a much greater drop than occurred in either of the Kilauea Sugar Plantation Company tests. The cause is not known, although there is the suspicion that many of the rats that had survived the recent torpedo campaign (March 28 to April 2) were bait-shy and refused to eat strange food. However, in spite of all handicaps, 14.6 pounds of poisoned grain were consumed in 240 stations, resulting in a large number of rats being killed which had lived through the torpedo campaign of only 3 weeks previous. A larger amount of unpoisoned oats was consumed on account of the necessary extra days of feeding. This increased the ratio to one pound of poisoned to 8.3 pounds of unpoisoned grain. Experiments Nos. 1 and 2 at Kilauea Sugar Plantation Company showed ratios of 1 :4.4 and 1 :5.3 respectively.

For experimental purposes the poison was left in the field a second period of 5 days after the first record had been taken. There were 39 stations or 12 per cent which showed some disturbance of the poisoned grain with a total of .7 pound eaten during the 5 days. This amounts to 5 per cent of the amount eaten during the first 3 days of poison. In this case it might be worth while to let the poison stay 4 days before removing, in order to catch those rats that were slower in returning to feed.

Distribution of Rat Population:

The detailed data on Experiment 1, Grove Farm Company, station by station, have been plotted on the map of the field shown in Fig. 19. The legends used are the same as those previously described for the Kilauea tests. By this method a graphic picture is presented of the distribution of the rats in the field in relation to natural cover occurring around the field.

The areas along the clean open pasture harbored comparatively few rats, as was also the case at Kilauea. There were 56 stations in various locations along the pasture and across the field on the ditchman's trail which were never visited during the entire period of the test (see Fig. 19). These areas were entirely free of rats. The rat population was unknown throughout some fairly large inside areas which were inaccessible at this stage of growth of the cane. According to the results from Kilauea we believe that most of the rats (not all) can be drawn greater distances to feeding stations than 100 feet or even 200 feet. In order to poison rats that have become established in unirrigated big cane, it would be necessary to provide access every 200 to 250 feet. However, this should not be necessary if the poison campaign were carried on early enough along the edges of permanent rat cover adjacent to fields of young cane.

An extremely heavy infestation of rats occurred along the gulches where the natural cover made the areas almost impenetrable. Bordering these areas there

were many distinct and clear-cut trails through the grass from the gulch into the cane. This was less pronounced at Grove Farm Company than in some locations at Kilauea. This map points out the areas of greatest rat population, and suggests that the early treatment of the adjacent cover, while the cane is small, would be the most effective and economical control.

Unpoisoned Oats Following the Poisoned:

After 8 days of poisoned, unpoisoned oats were again exposed for 5 days in all stations, to check upon the effectiveness of the poison. More than half of the stations had been visited in that 5-day period and oats consumed amounting to daily acceptance of 3 per cent per active station. This totalled 6.5 pounds for 5 days or an average of 1.3 pounds per day for the entire field (143 acres). These revisited stations were mostly along the gulch cover and indicated that either new emigrants were coming from the gulch or that some rats were able to detect the difference between poisoned and unpoisoned oats.

The number of rats could not have been large as one rat could do a lot of visiting and eating in a 5-day period; but it does indicate that the gulch areas must be poisoned thoroughly, as is recommended in detail in this article.

Subsequent Treatment and Final Report on Field 23:

W. P. Alexander, manager of Grove Farm Company, has reported that the field was poisoned again in June and harvested during August. He has kindly supplied us with data "on the rat population as indicated by the catch by dogs behind the harvesting gang." He states that "the following figures showing a relatively small number of rats per acre were confirmed by the observation that there was much less rat-eaten cane in this field which was badly damaged a year ago."

Rats Caught by Dogs

	Total	Per acre
Field 23 (143 acres), crop 1937 (15 months)	408	2.9
Field 23, crop 1936 (22 months)	1716	13.5
All fields—crop of 1936		12.0
To date—crop of 1937		10.1

These data offered by Mr. Alexander indicate a marked improvement in rat control which would have been more complete if certain areas had been accessible for treatment.

Summary:

This experiment was carried on during the period of April 9 to May 4th. The general plan of operation was the same as at Kilauea, but differed in that unpoisoned grain was exposed longer before the final poisoning, due to a slower acceptance by the rats. A very recent field poisoning with torpedoes had apparently made the remaining rats doubly cautious toward new food. However, the general results were the same as at Kilauea, but with a reduced efficiency. As at Kilauea, the rats were

most numerous along the gulch areas and wasteland where permanent cover is always present. The same suggested control measures—an early intensive campaign concentrated along the natural rat harbors adjacent to young cane—apply equally well to Grove Farm Company.

The final results of the rats caught at harvest show a greatly reduced population in this treated field compared with the previous (1936) crop and also to the rest of the fields for the present (1937) crop.

Conclusions

1. The prebaited feeding-station method is effective and economical in poisoning rats in large field areas.

2. One round of poisoning may be made for as low as 30 cents per acre.

3. Six or more days of prebaiting with unpoisoned grain are necessary before poisoned grain should be substituted; the poisoned grain should remain in the field not less than 3 days.

4. Experimental work demonstrated that rats are most numerous and do the greatest damage along the edges of big cane bordering the heavy undergrowth of wastelands, particularly gulches and drains.

5. The prebaited feeding stations should be concentrated along the edges of young cane adjacent to natural rat cover or close to recently harvested fields.

6. We believe that if the area has been thoroughly and effectively covered the procedure need not be repeated for at least 3 months.

7. The success of this rat control method rests directly with the men in the field who are responsible for the intelligent distribution and handling of the feeding stations.

8. Curved galvanized iron covers placed over small square baking pans have proved to be the best feeding-station equipment.

9. Spacing between stations will vary with local conditions, but an average of four stations per acre should be sufficient for large field areas.

10. The approximate cost of station equipment is about 18 cents each. The cost for permanent equipment to serve 100 acres at 3-month intervals would be $8.00.

11. Rolled oats are the most satisfactory bait which has been tested.

12. The sweetening of the poisoned bait is a definite benefit.

13. A concentration of thallium sulphate in the poisoned bait of one part in two hundred should be sufficient for the prebaited feeding stations.

14. The best attrahents found thus far are corn oil, raw linseed oil, and coconut oil, in that order. One quart of oil is sufficient for 10-15 pounds of rolled oats.

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Utilization of Molasses—II

PEN-FATTENING OF BEEF CATTLE ON MOLASSES AND OTHER BY-PRODUCT FEEDS

(EXPERIMENT AT HAMAKUA MILL COMPANY)

By Alvin R. Lamb

Introduction

It has been previously noted by the writer* that although about 80 per cent of the beef consumed in the Territory of Hawaii is locally produced, the remaining 20 per cent is imported from the mainland United States. This is used by the Army and Navy and by a group of other consumers who demand a certain quality which is generally obtained only by a final fattening period in small lots on concentrated rations. This system is called dry-lot feeding in the Middle West, to distinguish it from pasture feeding. We have chosen to use the term "pen-fattening," in order to make a definite distinction from fattening on grass pastures or paddocks, which commonly vary in size from 20 to 200 or more acres.

The size of the pens generally used is of the order of two thousand square feet for each 20 head of cattle. This amount of space is ample, but prevents much exercise, which is not desirable in the final stage of beef production. In this system of feeding, which produces most of the good beef marketed in the United States, the cattle make good gains over a three to four months' feeding period—provided they are not too fat at the outset—and become very tame and quiet, thus decreasing difficulty in handling and the losses due to bruising of the meat at marketing time. The muscles become softer and the meat thereby more tender, and the scattered deposition of fat in the muscle itself, which is described as "marbling," is considerably increased. This last factor makes a marked improvement in the market grade of the carcass and in the flavor of the cooked meat.

This system of feeding, using a ration including as much as possible of local by-products, has been tested in a steer-feeding experiment at the Hamakua Mill Company, Paauilo, Hawaii. The only previous experiment with this type of ration was conducted in 1928 at the Waianae Company, by Eremeef and Lennox.† They used a ration of molasses, bagasse and soybean oil meal substantially the same as that employed by Naquin in feeding mules at Honokaa‡ and their 10 steers gained an average of three pounds each per day over a period of 89 days. No data were shown on the quality of meat produced, but the value of the ration in producing good gains in feeder steers was conclusively demonstrated.

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* Utilization of Molasses. The Use of Cane By-Products in Fattening Beef Cattle. The Hawaiian Planters' Record, 40: 121-125, 1936.

† Steer "Dry Lot" Fattening Experiment. The Hawaiian Planters' Record, 35: 341-344, 1931.

‡ Cane Pulp as a Carbonaceous Food for Animals. The Hawaiian Planters' Record, 33: 407-409, 1929.

Other systems of fattening beef under Hawaiian conditions, especially those which have been recently tested in cooperative experiments under the direction of the Hawaii Agricultural Experiment Station, will be discussed below. The adaptability of these various systems of feeding, which employ sugar cane by-products, to the various climatic and other conditions in the Territory, will also be discussed.

Experimental

Forty-seven head of two-year-old steers were selected at Kukaiau Ranch, with uniformity in type and conformation as the main considerations. The animals available were found to be in too high condition—i.e., too fat—to be economical feeders. Since, however, the chief purpose of the experiment was to compare the quality and finish of the beef produced on pasture with that produced by pen-feeding, these steers were considered as acceptable. The uniformity of the average gains in the three lots indicated, at the end of the experiment, that a fairly satisfactory degree of uniformity between the lots had been secured.

These steers were driven to the plantation (Hamakua Mill Company, Paauilo, Hawaii) and were weighed and eartagged. Each animal, as it was weighed, was graded on type, condition and temperament. They were then allotted very carefully, on paper, to three groups of 15 steers each, the three groups containing the nearest possible to an equal distribution in beef type, condition of fatness, weight, and quiet or nervous temperament. In order to eliminate any possible unconscious prejudice, these three groups were then assigned to pasture or pen-feeding by drawing lots. Lot 1 was assigned to the pasture and Lots 2 and 3 to pen-feeding.

The steers were weighed again on the two following days, to secure a true average initial weight. On the last day they were divided into their proper groups, and Lot 1 was driven to the pasture, a distance of about three-quarters of a mile.

The pasture available, at about 1500 feet elevation, contained approximately 80 acres for the group of 15 steers, plus the two extra steers which were kept with Lot 1. The forage in this pasture was estimated to be composed as follows: *Commelina nudiflora* (honohono) 5 per cent, *Tricholaena rosea* (Natal redtop) 20 per cent, *Cynodon dactylon* (Bermuda grass) 5 per cent, *Panicum barbinode* (Para grass) 5 per cent, *Paspalum digitatum* (Hilo grass) 40 per cent, *Desmodium uncinatum* (Spanish clover) 10 per cent, and various weeds and unidentified grasses, 15 per cent. Rain had been abundant and growth was excellent, and a good water supply was easily available to the steers.

Groups 2 and 3 were placed in corrals adjoining the mule-shed on the plantation. These lots were well shaded, and each contained about 1500 square feet, with the scale house and another small corral located between the two lots. Feed troughs were placed along the fence, and each lot was supplied with a water trough equipped with a constant-level intake valve. Each water trough was flushed out daily, and the feed troughs were cleaned and washed each morning before feeding. A general view of the feed troughs and scale house, and some of the cattle in Lot 3 are shown in Figs. 1 and 2.

The rations fed were as follows, with the nutrients calculated on the basis of average analyses:

Fig. 1. Feed troughs and scale house. Roofs were later placed over the troughs to prevent serious washing of the feed by rain.

Fig. 2. Steers in Lot 3, after six weeks' feeding.

TABLE I

COMPOSITION OF RATIONS

	Total lb	Digestible crude protein lb	Total digestible nutrients lb
Lot 2			
Screened bagasse	32	.25	16.00
Molasses	38	.35	22.80
Pineapple bran	12	.10	7.20
Soybean oil meal	16	6.25	13.60
Steamed bone meal	1	...	....
Salt	1	...	....
	100	6.95	59.60
Lot 3			
Screened bagasse	24	.20	12.00
Molasses	38	.35	22.80
Pineapple bran	20	.16	12.00
Soybean oil meal	16	6.25	13.60
Steamed bone meal	1	...	....
Salt	1	...	....
	100	6.96	60.40

Four samples of these rations, taken at intervals of one week during the experiment, were chemically analyzed. The average analytical results are shown in Table II.

TABLE II

ANALYSIS OF MIXED FEEDS

	Lot 2 %	Lot 3 %
Moisture in air-dry sample	5.67	5.77
Crude protein	11.42	11.83
Crude fat	2.43	2.65
Crude fiber	14.17	13.80
Ash	7.00	7.06
Nitrogen-free extract	59.31	58.89
	100.00	100.00

In addition to the above mixed ration, chopped cane tops were fed in an average amount of 10 pounds per steer per day. The nutritive ratios of these rations, including the cane tops, and calculated on the basis of the average feed consumption for the whole period, are 1 :8.0 and 1 :8.1 respectively.

The mixed ration was fed twice daily, early morning and afternoon, at a regular hour. About two hours later, when the mixed feed had been largely consumed, one-half of the day's allowance of chopped fresh cane tops was given. The steers found this very appetizing, and stayed at the feed trough until the feed was, on most days, all consumed.

TABLE III

GAINS AND MARKET DATA ON STEERS

Steer No.	Lot No.	Sire	Dam	Average initial weight lb	Final weight lb	Total gain lb	Carcass No.	Carcass weight lb	Dressing %	Carcass grade	Selling price cts. per lb	Remarks
							Lot 1 (control on pasture)					
6	1	[illegible]	[illegible]	922	1095	173	46	579	52.9	Med.+	$18\frac{1}{4}$	Prices of carcasses corrected by restoring discounts for bruises
7	1	[illegible]	[illegible]	932	1014	82	26	[illegible]	54.5	Good—	$18\frac{1}{4}$	
32	1	[illegible]	[illegible]	1025	1169	144	44	[illegible]	55.7	Good	$18\frac{1}{4}$	
8	1	F	I	891	1025	134	21	[illegible]	52.7	Med.	18 (corr.)	
87	1	G	[illegible]	1013	1135	122	15	[illegible]	56.6	Good—	[illegible]	
[illegible]	1	F+	[illegible]	862	970	108	27	[illegible]	55.9	Med.+	18	
[illegible]	1	F	I	876	1022	146	23	[illegible]	55.0	Med.—	$17\frac{3}{4}$	
[illegible]	1	G	F	1093	1170	77	13	[illegible]	57.1	Med.+	$17\frac{3}{4}$ (corr.)	
[illegible]	1	F+	[illegible]	873	990	117	9	[illegible]	54.2	Med.+	$18\frac{1}{4}$	
[illegible]	1	G	[illegible]	938	1045	107	45	[illegible]	54.6	Med.	18	
70	1	I	I	908	1012	104	47	[illegible]	54.9	Med.	18	
[illegible]	1	[illegible]	[illegible]	986	1100	114	31	[illegible]	54.3	Med.	18 (corr.)	
[illegible]	1	F	F	898	1010	112	3	[illegible]	55.0	[illegible]	$18\frac{1}{4}$	
[illegible]	1	[illegible]	I	971	1030	59	20	[illegible]	57.0	Med.	$18\frac{1}{4}$ (corr.)	
[illegible]	1	I	[illegible]	946	1085	139	24	[illegible]	54.9	Com.	$17\frac{1}{2}$ (corr.)	
[illegible]										3 Good	18.07¢ (corr.)	Actual average price received 17.98¢
Means				942	1058	116		[illegible]	54.9	14 Med.		
										1 Com.		
							Lot 2 (open fed)					
5	2	[illegible]	[illegible]	1028	1100	72	[illegible]	600	[illegible]	Good	[illegible]	
[illegible]	2	I	I	999	1045	115	[illegible]	581	[illegible]	Good	$18\frac{1}{2}$	
[illegible]	2	[illegible]	I	1001	1071	70	[illegible]	[illegible]	[illegible]	Med.+	18	
84	2	[illegible]	[illegible]	992	1066	74	[illegible]	[illegible]	[illegible]	Good	$18\frac{1}{2}$	Total mixed feed 35,385
[illegible]	2	I	I	849	1005	156	[illegible]	[illegible]	[illegible]	Med.	$17\frac{3}{4}$	weigh back 1,512
[illegible]	2	I	[illegible]	959	1025	66	[illegible]	[illegible]	[illegible]	Good	$18\frac{1}{2}$	
[illegible]	2	[illegible]	I	1109	1137	28	[illegible]	[illegible]	[illegible]	Good	$18\frac{1}{4}$	net 33,873 lb
[illegible]	2	[illegible]	[illegible]	898	1030	132	[illegible]	[illegible]	[illegible]	Med.	$17\frac{3}{4}$	Total cane tops 15,214 lb net
[illegible]	2	I	[illegible]	910	998	88	[illegible]	[illegible]	[illegible]	Med	$17\frac{3}{4}$	
[illegible]	2	[illegible]	I	1027	1086	59	[illegible]	[illegible]	[illegible]	Good	$18\frac{1}{2}$	
74	2	I	[illegible]	949	995	46	[illegible]	[illegible]	[illegible]	Med.	18	
[illegible]	2	[illegible]	[illegible]	903	1040	137	[illegible]	[illegible]	[illegible]	Med.	18	
[illegible]	2	[illegible]	[illegible]	990	1107	117	[illegible]	[illegible]	[illegible]	[illegible]	$18\frac{1}{4}$	
[illegible]	2	[illegible]	[illegible]	945	1020	75	[illegible]	[illegible]	[illegible]	Good	[illegible]	
[illegible]	2	[illegible]	[illegible]	908	1110	202	[illegible]	[illegible]	[illegible]	Med.+	$18\frac{1}{4}$	
Means				958	1054	96		[illegible]	[illegible]	7 Good	18.20¢	
										8 Med.		
							Lot 3 (open fed)					
[illegible]	3	[illegible]	[illegible]	933	1035	102	12	584	[illegible]	Good	$18\frac{1}{2}$	
[illegible]	3	[illegible]	[illegible]	985	1130	145	7	648	[illegible]	Good	$18\frac{1}{2}$	
[illegible]	3	[illegible]	[illegible]	893	1020	127	19	597	[illegible]	Good	$18\frac{1}{2}$	Total mixed feed 34
89	3	[illegible]	I	965	1075	110	22	581	[illegible]	Med.	18	weigh back 1
[illegible]	3	I	[illegible]	1041	1097	56	11	606	[illegible]	Med.+	$17\frac{3}{4}$	
[illegible]	3	[illegible]	I	1028	1200	172	17	677	[illegible]	Good—	18	net 33,234 lb
[illegible]	3	[illegible]	F	1014	1060	46	10	611	[illegible]	Med.	$17\frac{3}{4}$	
[illegible]	3	[illegible]	[illegible]	907	1000	93	44	577	[illegible]	Med.+	$18\frac{1}{2}$	Total cane tops 15,345 lb net
[illegible]	3	[illegible]	[illegible]	973	1055	82	35	599	[illegible]	Good	[illegible]	
18	3	[illegible]	[illegible]	937	980	43	6	589	[illegible]	Good—	[illegible]	
76	3	F	[illegible]	846	955	109	42	530	[illegible]	Med.+	$18\frac{1}{4}$	
88	3	F	I	957	1150	193	18	641	[illegible]	Good	$18\frac{1}{2}$	
83	3	I	F	880	1025	145	28	577	[illegible]	Good	$18\frac{1}{2}$	
63	3	[illegible]	[illegible]	842	930	88	39	524	[illegible]	Med.+	[illegible]	
78	3	F	I	919	1060	141	16	580	[illegible]	Med.	18 (corr.)	
Means				941	1052	110		591	[illegible]	8 Good	18.23¢ (corr.)	Actual average price received 18.22¢
										7 Med.		

At the beginning of the experiment the steers received cane tops only for the first two days. On the third day one pound of the molasses mixed feed was given for each animal. On the two following days three pounds were allowed per animal per day. This was increased thereafter at a rate of from one to three pounds per day, with a corresponding reduction in the amount of cane tops, until the allowance for each steer had reached 20 pounds per day, plus 10 pounds of cane tops. The amount of mixed feed was then gradually increased to a maximum of 29 pounds per day. The allowance of cane tops was decreased to five pounds per steer, but this was immediately thereafter increased to 10 pounds, which seemed to be the proper amount.

During the last three weeks of the experiment a change was made in the ration of Lot 2. The amount of bagasse was reduced to 18 per cent, and the pineapple bran increased to 26 per cent, to determine whether or not this mixture would be more appetizing, inducing a greater consumption of feed. Such a possible effect, however, during the short time indicated, was nullified by the somewhat disturbing effect of the change. Nevertheless it seems probable that the 32 per cent level is a little too high for bagasse, considering the factor of appetite. This is in accord with the observations of Professor Henke on dairy cattle.

The feed was given according to the appetite of the steers, allowing them all they would eat, decreasing the amount slightly if they left as much as 10 per cent. The average amount weighed back and discarded was, as shown in Table III, approximately 4.3 per cent. The feeding, which is a very important matter in economical beef production, was well done by the plantation herdsman, who had had considerable experience with dairy cattle, but had no previous experience with beef cattle. Observations on appetite, weather, and condition of the animals were carefully recorded throughout the experiment. A single steer was "off-feed" for a week early in the experiment. There was no case of "bloating" and no other similar trouble.

Factors which decreased the rate of gain were a certain amount of excitement at the monthly weigh day, and the amount of mud in the lots. The latter condition was much worse than anticipated, and it was necessary to disturb the animals considerably during a month or more by the hauling and distributing of a large amount of rock and gravel. This procedure seemed essential, although steers are not usually hampered in their gains by mud, if a reasonably dry area can be provided where they may lie down. There is no necessity for shelter in this climate, if part of the lot can be kept dry in rainy weather by having it properly graveled or concreted, at a slightly higher level than the rest of the lot.

Weighing the animals on three successive days was necessary in order to secure a nearly correct average initial weight, on account of the great variations in stomach and intestinal contents. This should also have been done at the end of the experiment, but it was so inconvenient to do so that only one final weight was taken. The average of the weights of 15 steers tends to smooth out some of this variation.

The monthly weights were necessary in order to judge the progress of the feeding. In ordinary feeding for market, not on an experimental basis, most of this weighing would be eliminated, and the removal of this considerable disturbance to the appetite of the animals would increase the gains.

The steers in Lot 1, pasture-fed, were not disturbed during the experiment, only the initial and final weights being taken.

Marketing and Grading the Beef

After a feeding period of 96 days, all three groups were weighed and marked with paint to insure correct identification of the carcasses. The steers were then shipped by rail to Hilo and by steamer to Honolulu, where they were slaughtered at the Hawaii Meat Company's plant. By the courtesy of this company, the writer was given every opportunity to check the identity of each animal as it was slaughtered, and to secure all the data desired on each carcass. The Federal officer in charge of meat inspection in Honolulu, Dr. L. Bilikam of the U. S. Bureau of Animal Industry, made a careful inspection of each carcass in the cooling room. Without knowing the experimental treatment of any carcass, he graded each one according to official government inspection standards, which consider mainly the quality, finish and conformation of the carcass. The significant results of this grading are shown with other data in Table III.

In making the above-described grading no attention was paid to bruises, which have no direct relation with the results of the feeding experiment. The purchaser, however, discounted each carcass showing ante-mortem bruises from one-fourth to one cent per pound. The effect of pen-feeding on the quietness and tameness of the steers is evidenced by the fact that five of the 15 pasture-fed steers showed bruising, while only one of the 30 pen-fed animals was bruised.

Discussion

A study of the detailed data in Table III brings out a number of important facts. It is probable that the care in allotting the animals and the fairly large number in each group make the averages a true picture of what was obtained under the conditions which existed in this experiment. The average gains, therefore, may be taken as showing what may be done with feeders as nearly ready for market as these were, disturbed as these were by several weighings and under unfavorable weather conditions.

The total gains, which were practically the same in all groups, were unsatisfactory. The rations fed, however, would produce much greater gains—as they have elsewhere—with thinner animals. Two of these steers gained 200 pounds each during the experiment, one of them having gained over four pounds per day during the first 30 days. A number of others put on approximately 150 pounds. Those which made small gains, such as numbers 63, 97, 69, 74, 59, 90, and 68, show by their yield of dressed carcass that they were already very fat. The average dressing percentage of these seven steers was 58.1 per cent, while the average of all the other pen-fed steers was 55.5 per cent.

A significant difference between the pasture-fed and pen-fed steers appears in the average dressing percentage by groups. Lot 1 averaged 54.9 per cent, and Lots 2 and 3 averaged 56.1 per cent and 56.2 per cent respectively.* These figures show

* The standard deviation ("standard error") of the mean dressing percentage of the pasture-fed steers is 0.324 per cent. If Lots 2 and 3 are combined, the standard deviation of the mean dressing percentage of the group of 30 steers is 0.321 per cent. The difference between the mean dressing percentages of the pen-fed and pasture-fed steers (56.15—54.9) is 1.25, and the standard deviation of this difference is 0.456. The former is 2.74 times the latter, which figure corresponds with odds of 173 to 1 that this difference in dressing percentage is significant.

the relation of the weight of the dressed carcass to the live weight of the animal, and indicate a greater yield of marketable carcass from the pen-feeding. It may also be noted that the highest individual dressing percentage in the pasture-fed group was 57.1 per cent, while Lots 2 and 3 produced seven steers which exceeded this, one being as high as 60.1 per cent. This is unusually high, when it is considered that these animals received no feed for four days after the final live weights were taken, and before they were slaughtered.

The most important data bearing on the results obtained by pen-feeding in contrast to pasture-fattening appear in the carcass grades shown in Table III. As previously stated, the steers were allotted as evenly as possible at the beginning of the experiment with particular attention to beef type, conformation and condition. Nevertheless, in the pasture-fed group the carcasses rated 3 good, 11 medium, and one common. The two pen-fed groups produced 7 good, 8 medium; and 8 good, 7 medium carcasses respectively. This is apparently due to the fat having been better and more evenly distributed, as well as to the tendency to favor the deposition of fat instead of the growth of muscle tissue under the conditions of pen-feeding. The price per pound paid by the purchaser for these carcasses, which depends somewhat on the total weight as well as on the quality and condition of the carcass, was in most cases correlated with Dr. Bilikam's grading although entirely independent of it. These prices are also shown in Table III.

Unfortunately it was not possible to make controlled comparative tests on the quality and flavor of the meat when cooked. Several cuts of representative carcasses, however, from both control and pen-fed animals, were cooked by the writer under comparable conditions. The difference in juiciness and flavor, apparently referable to the extent of "marbling," was definitely in favor of the pen-fed carcasses. The Army and Navy officers who are actively engaged at present in inspecting meats for all the service units in Hawaii saw several representative carcasses and stated that they were at least as good as the beef which is currently imported from the mainland.

The illustrations of cuts from some of these carcasses (Figs. 3 and 4) show plainly the difference in marbling, or deposition of fat between the bundles of muscle fibers. The tendency to deposit fat in these locations comes naturally in a fairly well-fed steer about three years old or more, and is increased, as well as brought about at an earlier age, by the conditions of pen-feeding. In fattening beef animals this type of fat deposition is greatly preferred as it lessens the waste due to the accumulation of large masses of fat external to the muscles and in the abdominal cavity. The factor of waste as well as the improvement in quality and flavor of the meat from properly marbled carcasses lead to discrimination by buyers in favor of this type of carcass if prices are comparable, or to the paying of a higher price in a well-established market.

The deposition of fat, in any location, is the most expensive part of the process of beef production. This is on account of the fact that fat contains 2.25 times as much energy as carbohydrate or protein. The amount of extra feed which would deposit one pound of fat would be enough for 2.25 pounds of body protein, besides the weight of the amount of water which is a normal part of muscle tissue, but not of fat. This tendency of animals to deposit more fat and less protein in the later

Fig. 3. Cross-sections of loin at "first" rib, from two of the best pasture-fed steers. (These are not quite typical of Lot 1, since No. 14 rated "Good," and No. 15 "Good—." They were the only carcasses from this lot available for photography. No. 14 is one of the two extra steers brought down from the ranch, not included in the data, but which were carried along with Lot 1 on pasture. Final live weight of this steer was 1135 pounds.)

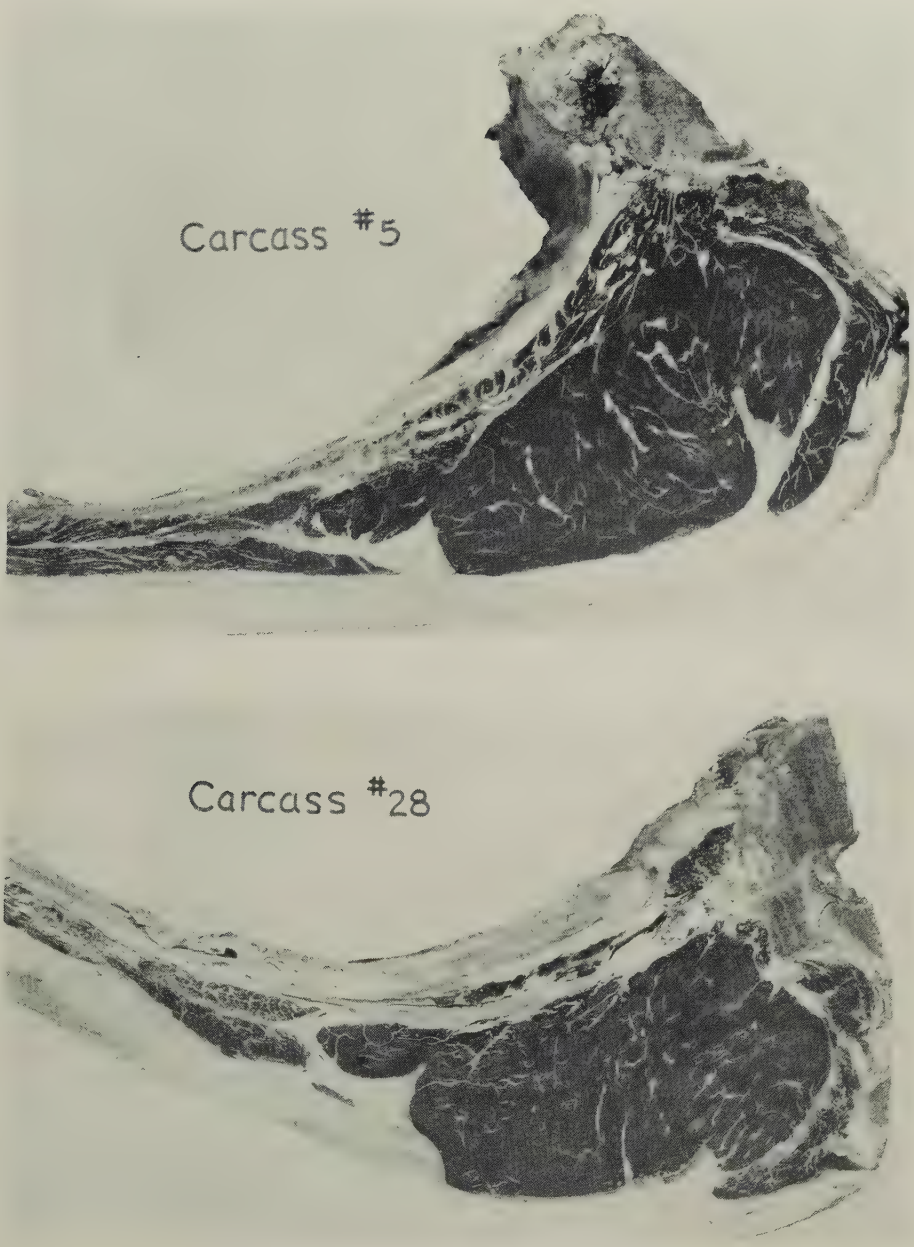

Fig. 4. Cuts from the same location as those shown in Fig. 3. No. 5, from Lot 2, rated "Good," and No. 28, from Lot 3, rated "Good—." Note the marbling, in comparison with Lot 1.

stages of fattening is well shown by the work of Trowbridge, Moulton and Haigh.* A typical comparison from their careful and extensive work on this subject indicates that the first 500 pounds gain of a young steer consisted of fat 46 per cent, protein 12 per cent, water 40 per cent. The second 500 pounds gain, bringing the steer to a prime condition, consisted of fat 68 per cent, protein 6.6 per cent, water 22 per cent. It is this and the high energy content of fat which make the later gains the most expensive, as well as the most valuable to the consumer. This also shows why it is necessary for profitable feeding, to start the fattening process with thinner or younger animals than was done in this experiment.

Another necessity is the use of cheap feeds. This can be met on the plantation by the use of molasses, bagasse and cane tops for the greater part of the ration. Further possibilities for cheapening the cost of the ration are in the growth of protein crops, the production of yeast protein from molasses, and the use of fish meal locally produced to avoid the importation of protein feeds.

Steers may be taken from a good range at an earlier age than was done in this experiment, but not too young, as their growth requirements would then necessitate too high a proportion of the more expensive protein feeds in the ration. It is probable that steers could be started on pen-feeding at six months younger than the animals in this experiment, if taken from a range of comparable quality and rainfall. Further comparison of the results from fattening cattle at different ages would give definite data on this point.

Other systems of fattening will give excellent results under proper conditions. The feeding practices in this Territory will undoubtedly develop in the direction of variable or elastic plans based on climatic or other local conditions. It seems probable that on range areas which are often short in rainfall and in which cattle have to travel considerable distances to secure their feed it will be found profitable to depend more on pen-fattening to finish the cattle. Other ranges which are fortunate enough to have lush pastures, at least in years of good rainfall, may find it preferable to finish their cattle on grass in relatively small paddocks, feeding molasses in tanks as a supplement, which will reduce the amount of exercise necessary for the cattle to secure the necessary feed intake. Some cattlemen who are using this plan are also feeding some protein supplement in the molasses. This plan probably will produce the cheapest gains, but will not usually produce a high percentage of good carcasses which will meet the demands of those who are now importing beef. That particular market seems to be open to those beef producers who are in a position to use cheap cane by-products for feed. The extent of that market was discussed in the first paper of this series.†

Feeding Costs

In Table IV is presented a balance sheet showing the actual costs of this experiment. The steers were bought on the basis of the Honolulu price for the dressed carcass. The weight of dressed carcass was calculated from the live weight of the

* Composition of the Beef Animal and Energy Cost of Fattening. Missouri Agr. Expt. Stn. Res. Bul. 30, 106 pages, 1919.

† Utilization of Molasses. The Use of Cane By-Products in Fattening Beef Cattle. The Hawaiian Planters' Record, 40: 121-125. 1936.

steers as purchased by multiplying by the factor 0.55, which is the yield of carcass shown by the pasture-fed group when marketed. Variations in market price are eliminated by using for the cost price the price obtained for the pasture-fed steers at the time of marketing the cattle. Using the price of finished cattle for the initial cost may be appropriate in this case, as the steers were so nearly finished. Normal "feeders" in thinner condition should be bought at an appreciably lower price. In the latter case, with no great change in market price, there would normally be some profit in the price per pound of finished cattle, in addition to the return from the increase in weight.

TABLE IV

BALANCE SHEET

Debit		Credit	
Cost of 45 head steers*	$4,269.60	Cash received:	
Overhead costs:		Lot 1—15 head at 17.98¢	$1,567.23
Lumber, etc. for lots. $276.60		Lot 2—15 head at 18.20¢	1,614.48
Labor, construction and graveling 602.65		Lot 3—15 head at 18.22¢	1,614.56
$879.25			
One-tenth of overhead construction costs	87.93		
Labor—feeding and care	103.50		
Feed—imported	390.67		
Feed—local†	99.65	Loss	155.08
	$4,951.35		$4,951.35

* At 18 cents per pound of carcass, based on first day's weights.
Estimated dressed weight, 55 per cent of live weight.

† Molasses, 12.75 tons at $4.00.
Cane tops, 15.275 tons at $2.00.
Bagasse, 9.05 tons at $2.00.

Since the price paid for these cattle was based on the price of the carcasses delivered in Honolulu, the freight was paid by the ranch, and does not appear as such in Table IV.

The costs of construction of the feed lots, fences, scale house, etc., including the cost of putting in the gravel and rock during the experiment, are considered as overhead, and the amount charged against this single feeding operation is 10 per cent.

The cost of the imported protein feed was the greatest item in expense, and could be much reduced in practice by local production of protein feeds as suggested in the discussion above. These observations indicate the possibility of changing the loss shown here to a good profit, if changes in procedure suggested by this experiment are adopted. Thinner cattle of proper feeder type which would gain at the rate of two pounds or more per day, could be bought at a price lower than that paid for fat cattle. This would still be profitable to the rancher, for it would take the cattle from the range at an earlier age, leaving room for more calves on the same area and increasing the annual output of beef without much increase in the overhead costs of the ranch. This increased output would be the amount necessary to supply the beef

now imported from the mainland, and would go to that 20 per cent of the local consumers who now buy imported beef.

It is well within the abilities of the ranches of the Territory to supply this increased amount of beef, in animals of very good breeding, of quality such that this particular consumer demand would be easily satisfied when the cattle are finished as desired by these consumers. This experiment therefore furnishes an indication of a possible system of beef production, an additional benefit of which would be a cash return from the cane by-products, bagasse, cane tops and molasses.

Utilization of Molasses—III

FEEDING TRIALS ON LABORATORY ANIMALS TO DETERMINE THE VALUE OF BAGASSE, MOLASSES, AND KIAWE BEAN MEAL

By Alvin R. Lamb

It has long been the practice of stockmen to feed large amounts of wheat and oat straw, corn stover (dry stalks) and similar fibrous plant residues to animals which were merely being maintained over winter. It has thus been conclusively demonstrated that horses and cattle can derive considerable nourishment from such materials. It is well known that an appreciable amount of energy comes from the products of fermentation of such fibrous feeds in the paunch of ruminants and in the cecum of horses and mules. Dried bagasse, a material similar to corn stalks, has been used since 1927 by W. P. Naquin, at Honokaa Sugar Company, as 40 per cent of his regular ration for the plantation mules.* In this ration the bagasse is mixed with an equal amount of molasses (40 per cent of the total mixture) and with soybean oil meal (20 per cent) which supplies the necessary protein.

Bagasse Experiment

In order to secure more definite data on the actual value of bagasse under controlled conditions, an experiment using rabbits as subjects was started in July 1935. The rabbit is a herbivorous animal with an alimentary tract very similar in anatomy and function to that of the horse or mule, and is in that respect an excellent laboratory animal for such an experiment. In order to make the experimental conditions more nearly comparable with those of work animals the rabbits were exercised daily except Sunday in a machine (Fig. 1) which was rotated by an electric motor at such a rate that the animals traveled somewhat leisurely at a rate of 1,680 feet per hour. The amount of this exercise during the experiment will be given later.

The rations fed were as follows:

Group A-1 (control)	%	Group A-2	%
Alfalfa meal	50	Bagasse (sifted)	55
Rolled barley	25	Molasses	26.5
Molasses	25	Soybean oil meal	18.5
	100		100

These rations yield 8.0 per cent of digestible crude protein, with a nutritive ratio of 1:6.8.

Four young rabbits, females and litter mates, were taken at an average weight of 930 grams, two rabbits to each group. All received the control ration for the first 30 days, after which Group A-2 was gradually started on the bagasse ration.

* Cane Pulp as a Carbonaceous Food for Animals. *The Hawaiian Planters' Record*, 33: 407-409, 1929.

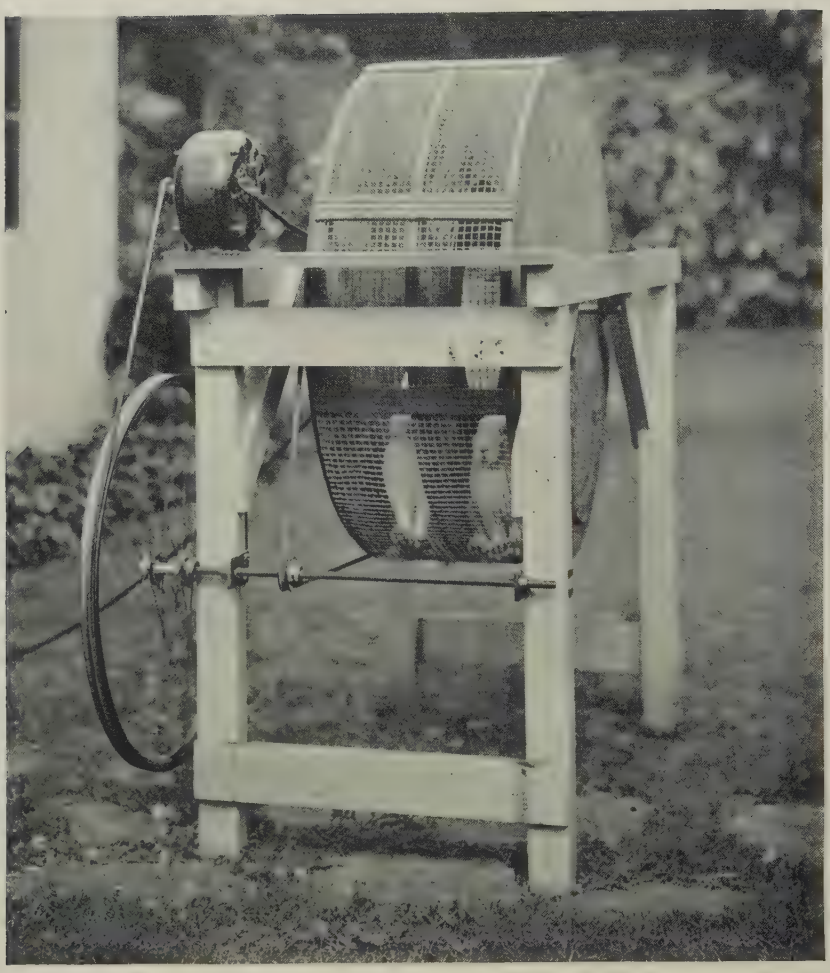

Fig. 1. Exercising machine run by electric motor. Rate of rotation, 3 r.p.m.

During the next 10 weeks the amount of bagasse ration was increased and the control ration was gradually reduced to zero, after which time 25 grams of fresh cane tops were fed daily to each rabbit in Group A-2. It was anticipated that young rabbits would not secure enough nutrients from this experimental ration to make approximately normal growth unless some natural feed such as alfalfa were given during the first part of the growing period. This was the reason for the gradual withdrawal of the control ration. After the rabbits reached an average weight of 1700 grams, no more control ration was given, but the cane tops were given, as stated above, throughout the remaining 23 months of the experiment. It was apparently necessary to give this small amount of green feed to keep the animals in normal health. The amount of energy contributed by the green cane tops, however, was very small.

The average daily net feed consumption for the whole experiment was as follows:

Group A-1—150 grams.

Group A-2—159 grams, plus 23 grams cane tops.

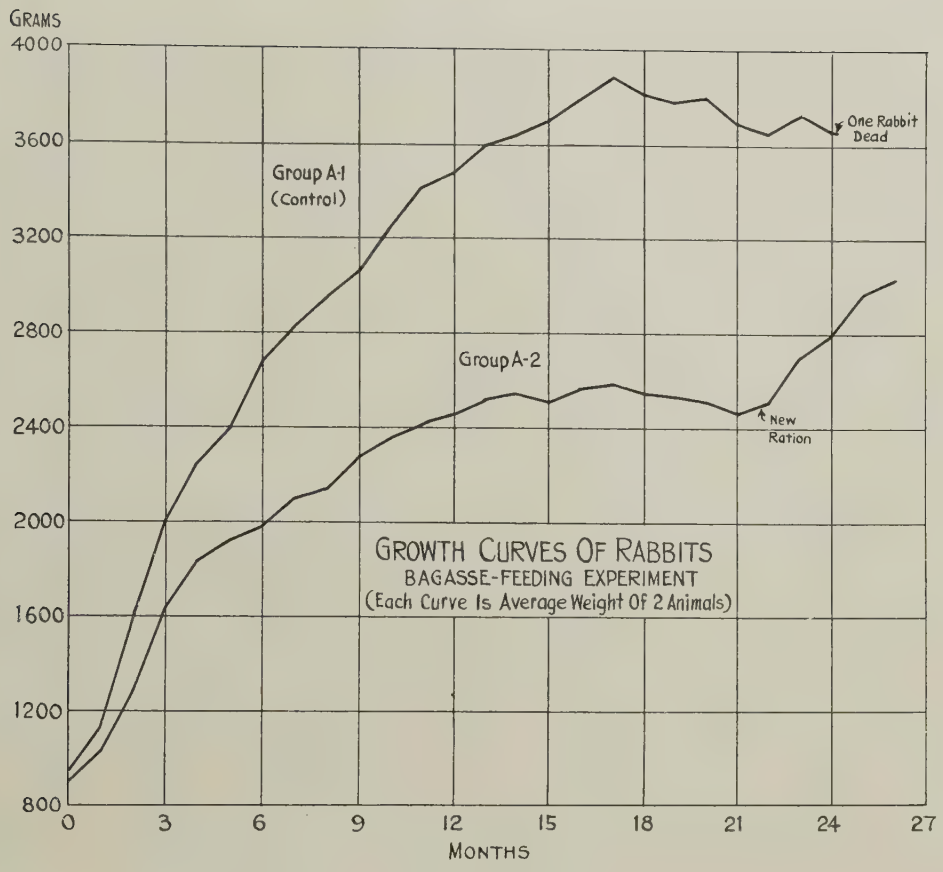

Fig. 2.

The figure for the bagasse group is higher than their actual consumption, on account of the physical character of this mixture. Although it was fed from hanging dishes, a considerable amount was scattered and lost in the litter.

Throughout the preliminary period the rabbits were being trained to exercise properly in the machine. This was quite a difficult process, but after the first two months they were exercising one hour per day, which rate was maintained for about one month. For the next seven months thereafter they exercised two hours daily, and for the next 10 months each received approximately two and one-half hours. It was obvious during most of this time that the bagasse rabbits, although they had not grown nearly as large nor as fat as the controls (see Fig. 2), were still quite fresh after the day's exercise, while the controls were usually tired and panting after the same amount of exercise. During the next two weeks, therefore, the controls received two and one-half hours exercise and the bagasse rabbits three hours. For four weeks thereafter the controls were given three hours and the bagasse animals three and one-half hours, with the latter still able to continue longer. The exercise was always given in one-hour periods or less.

Up to this time the experimental animals had received only the mixture which contained 55 per cent of bagasse, plus a small amount of cane tops, for a period of 18 months, and had done a considerable amount of work, the same amount or more

than the controls. This was apparently a demonstration that a considerable amount of energy had been metabolized from the bagasse, since these animals could not do this amount of work while continuing to gain weight, even slowly, on less than half the food intake (other than bagasse) of the controls.

A ration containing this large amount of bagasse (55 per cent) is, however, impractical. It was used only to give some information on the extent to which the bagasse may be utilized. The ration was changed at this point, therefore, to one which is suitable for plantation work animals, and which has been recommended for that purpose. At the same time the proportions of the control ration were also changed so that it would give the same proportions of nutrients, the nutritive ratios of the new rations shown below being 1 :8.0.

Group A-1

	%
Alfalfa meal	45
Rolled barley	20
Molasses	35
	100

Group A-2

	%
Bagasse (sifted)	33.3
Pineapple bran	16.7
Soybean oil meal	16.7
Molasses	33.3
	100

Plus cane tops, 50 grams per rabbit per day.

It may be easily seen from the curve in Fig. 2 that the new ration was much more efficient, as the animals immediately began to gain weight and continued to do so until the experiment was discontinued. The exercise was continued at the rate of about three hours each daily during the next two and one-half months, except that during one month of this time the bagasse rabbits received one-half hour more than the controls. At this time one control animal died, showing post-mortem evidence of intestinal obstruction. The other animal in this group appeared to be sick at this time, but quickly recovered. For the last one and one-half months of the experiment this control animal received two hours exercise and the experimental animals three hours.

The experiment was terminated on September 8, 1937, and the rabbits were killed. All were in good condition, with the skin, fur, muscle tissue, and visceral organs all macroscopically normal. Fig. 3 shows the appearance of these animals one week before the end of the experiment, which had continued over a period of two-thirds of the normal life span of the rabbit.

Kiawe Bean Meal Experiment

The extensive use of kiawe bean pods (from *Prosopis Chilensis*) for feeding livestock in many parts of the Territory has brought them into consideration as a possible part of rations utilizing our waste molasses, bagasse, and other by-products. There has been no previous information as to the nutritional value of the proteins of these pods, and some doubt has existed as to possible unfavorable effects from

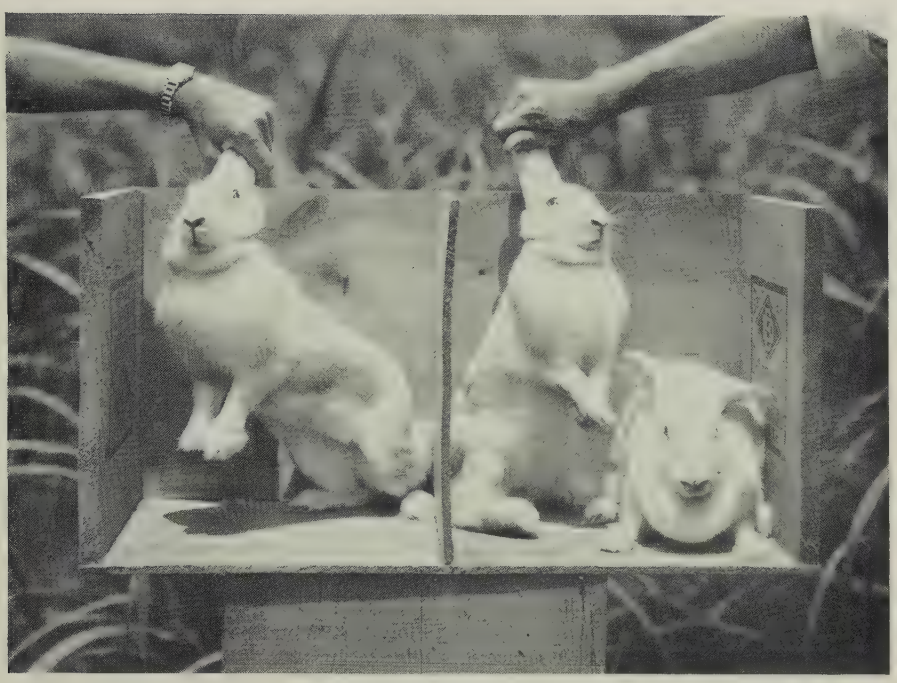

Fig. 3. At end of bagasse-feeding experiment. Control rabbit at left, two bagasse-fed rabbits at right.

feeding them in considerable amounts over extended periods. The Hawaii Agricultural Experiment Station has determined* the digestibility of the meal made from this material, and has used it as a part of hog and dairy-cow rations. In order to determine the protein value and the possible toxicity, however, a different sort of test, usually over a considerable part of the life cycle of small laboratory animals, is necessary. An experiment of this sort on a small scale has been carried on.

Five rabbits, litter mates, about eight weeks of age, were divided into three groups. The rations fed were as follows:

	Group B-1 (2 animals) %	Group B-2 (2 animals) %	Group B-3 (1 animal) %
Kiawe bean meal	99	90	30
Soybean oil meal	—	9	20
Molasses	—	—	21
Screened bagasse	—	—	28
Steamed bone meal	0.5	0.5	0.5
Common salt	0.5	0.5	0.5
	100	100	100

* Henke, L. A., and Work, S. H. Personal communications.

Representative samples of the kiawe bean meal used (from Hawaiian Commercial and Sugar Company, Puunene, Maui) have been chemically analyzed at the Station, showing the composition of the air-dry meal to be as follows:

	Moisture %	Crude fat %	Crude fiber %	Crude protein %	Nitrogen-free extract %
1935 crop	3.07	1.94	21.68	10.81	62.5
1936 crop	3.61	1.81	19.02	10.35	65.2

Vitamin additions were supplied to these rations in the form of one haliver oil capsule (three drops) and one-half of one "Rexall" dried compressed yeast tablet per animal. These materials were given twice weekly for the first ten weeks, and six times per week thereafter. This was planned to provide the necessary vitamin supplements in abundance, the mineral supplements necessary being also supplied equally to all three groups, in the form of bone meal and salt. Thus, the only probable deficiency in the first ration would be in the quality and amount of the protein. Unfavorable results might also be due, in the case of Group B-1, to some unfavorable or even toxic constituent in the meal.

In Group B-2, an increase in the protein content of the ration was made by adding 9 per cent of soybean oil meal, which contains over 40 per cent of protein of high quality. This was designed to furnish an abundance of a good protein supplement, leaving as the only factors which might affect the growth of the animals, a possible deleterious substance in the kiawe bean or a failure to consume enough of the ration.

In Group B-3 the ration included only 30 per cent of the factor under consideration, in combination with soybean meal and sugar cane by-products, to show the comparative value of a suitable local by-product ration including an amount of kiawe bean meal which seemed satisfactory for the practical feeding of plantation animals.

As is shown clearly in the accompanying curves (Fig. 4), this third ration was the most satisfactory. The second group (B-2) gained much better than Group B-1, indicating that the proteins of the kiawe bean meal are not complete enough to be satisfactory at a 10 per cent protein level, and are therefore improved by the addition of a protein supplement. The growth curve of Group B-2, however, is not as good as that of Group B-3, which may be due either to a failure to consume enough of the highly flavored feed, which might eventually become unappetizing, or to something unfavorable in the kiawe bean which had a slight effect on growth or appetite. Both of these possibilities would be related to the high content of kiawe bean (90 per cent) in the ration.

The sub-normal growth of Group B-1, (99 per cent kiawe bean) and their slightly rough-coated appearance, would be sufficiently explained by the protein deficiency, although other unfavorable factors could play some part. As would be expected, there was little or no attempt at mating in this cage, although Group B-2, on a better protein diet, was apparently normal. There was no reproduction, however, in this group.

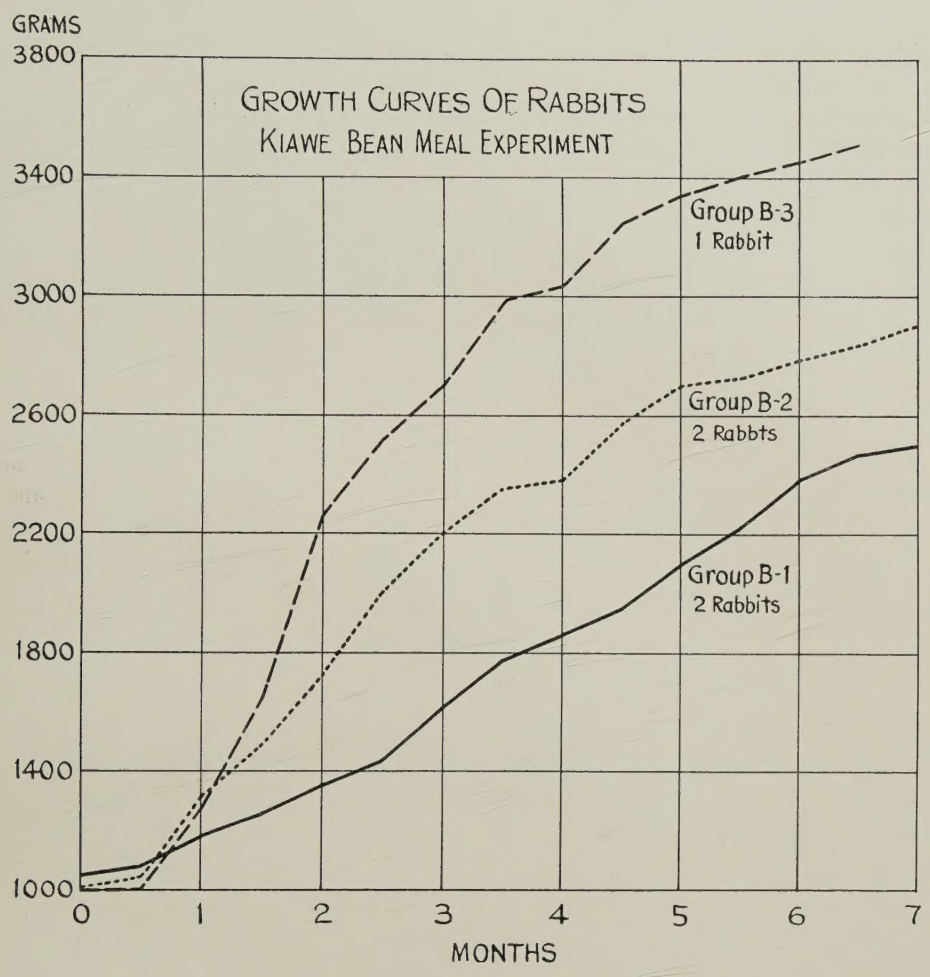

Fig. 4.

The average net feed eaten by these rabbits, including of necessity some waste, was as follows:

Group B-1—145 grams daily per animal.
Group B-2—142 grams daily per animal.
Group B-3—162 grams daily per animal.

Discussion

Using growing rabbits, the protein value of kiawe bean meal has been found to be somewhat less than optimum. Two animals receiving kiawe bean meal only (plus vitamin and mineral supplements) reached an average weight of 2500 grams in 7 months. When 9 per cent soybean oil meal was added to the ration, litter mates reached an average weight of 2900 grams. When 30 per cent kiawe bean meal was included in a ration of soybean oil meal, bagasse, and molasses, the single animal (litter mate of the others) on this ration weighed 3500 grams at the same time. This indicates that while kiawe bean proteins are not of optimum value, the material is

quite valuable as a part of the ration for these animals, and presumably for any herbivorous animal.

Kiawe bean pods are produced over large areas of waste land in this Territory. When dried they can be ground into a meal which is very palatable to livestock. As a part of by-product rations, including such materials as bagasse, cane tops, pineapple bran, rice bran, and molasses, they would contribute to the efficiency of such feed mixtures, and might well be used in greater amounts than at present. This would help to increase the efficiency of such feed mixtures, reduce the importation of feeds, and thus increase the use of our most important by-product, which is molasses.

Sugar Prices

96° Centrifugals for the Period
September 16, 1937 to December 9, 1937

Date	Per Pound	Per Ton	Remarks
Sept. 16, 1937..	3.42875¢	$68.58	Philippines, 3.40; Cubas, 3.405 and 3.43; Puerto Ricos, 3.48.
" 22	3.33	66.60	Cubas.
" 23	3.315	66.30	Puerto Ricos, 3.33; Cubas, 3.30.
" 27	3.25	65.00	Puerto Ricos.
" 28	3.20	64.00	Cubas.
Oct. 6	3.15	63.00	Cubas.
" 21	3.20	64.00	Cubas.
" 27	3.17	63.40	Philippines.
" 29	3.235	64.70	Cubas, 3.22; Puerto Ricos, 3.25.
" 29	3.2333	64.67	Cubas, 3.22; Puerto Ricos, 3.23, 3.25.
Nov. 3	3.22	64.40	Philippines.
" 5	3.2333	64.67	Cubas, 3.22, 3.25; Puerto Ricos, 3.23.
" 9	3.25	65.00	Cubas, Puerto Ricos, Philippines.
" 10	3.31	66.20	Cubas, 3.30; Philippines, 3.32.
" 12	3.34	66.80	Puerto Ricos, Cubas, 3.33; Cubas, 3.35.
" 16	3.32	66.40	Cubas.
" 18	3.3767	67.53	Cubas, 3.35; Puerto Ricos, 3.38, 3.40.
" 19	3.45	69.00	Puerto Ricos.
" 27	3.30	66.00	Cubas.
Dec. 3	3.35	67.00	Puerto Ricos.
" 6	3.30	66.00	Puerto Ricos.
" 7	3.28	65.60	Cubas.
" 9	3.20	64.00	Puerto Ricos.